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COUNCIL ON ENVIRONMENTAL QUALITY

ENVIRONMENTAL PROTECTION AGENCY

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This document contains ten papers concerning public policy aspects of nuclear waste management prepared for a conference on this subject held in October 1976. Sponsors included ERDA, NRC, NSF, EPA and CEQ. Purpose of the conference was to provide a forum in which to identify and discuss legal, institutional, social, environmental and other public policy issues relating to nuclear waste management. Overall topics covered included the following: Status and Key Issues in Current Waste Management Program, Goals of Nuclear Waste Management Program and Selection of Criteria for evaluating Policy Alternatives, Issues in Implementation of Nuclear Waste Management Program, and Organizational Responsibilities and Alternatives. Individual papers covered the following areas: description and explanation of the current program and technical alternatives available; criteria necessary for judging social and technological systems for managing nuclear wastes; appropriateness of present institutions for dealing with the long-term implications of nuclear waste; social, ethical and moral considerations; the interaction between scientific experts, decision-makers and the lay public; and finally, the relationship between nuclear waste management, nuclear fission and national energy policy.

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ERDA COMMERCIAL WASTE MANAGEMENT PROGRAM

by

Carl W. Kuhlman
Assistant Director for Waste Management
Division of Nuclear Fuel Cycle and Production
U.S. Energy Research and Development Administration

One of the very first programmatic actions of the Energy Research and Development Administration upon its formation last year was to review the nation's energy needs and the possible solutions offered by various energy systems. Nuclear energy obviously was an important part of the study. Realization of the potential contribution of nuclear energy was found to require solution of several problems in the commercial nuclear fuel cycle including the fundamental one of radioactive waste management. Therefore, a decision was made to decisively expand the attack on radioactive waste management across the board--both commercial waste and the waste at ERDA sites (previously AEC sites) accumulated from national defense programs. The commercial waste management program that developed from that decision is basic to this week's meeting.

This new look at the radioactive waste problems of the commercial fuel cycle began with an extensive analysis of the state of waste management technology which has been documented in a five volume Technical Alternatives Document.[1] This Technical Alternatives Document, or "TAD"

Presented at the "Conference on Public Policy Issues on Nuclear Waste Management" sponsored by the Council on Environmental Quality, National Science Foundation, Energy Research and Development Administration, Nuclear Regulatory Commission and Environmental Protection Agency, Chicago, Illinois, October 27, 1976.

as it is commonly called, was issued in May of this year and in July, a related public meeting was held in Denver. Although the July meeting included reviews of radioactive waste management policy by leaders of foreign countries and of various Federal agencies, considerable emphasis was given to the review of the contents of the TAD and direct discussions between interested members of the public and the technical experts who had been responsible for the various sections of TAD.

In addition to serving as a foundation for the expanded ERDA program, the Technical Alternatives Document was also intended to provide a technical basis for the preparation of a Generic Environment Impact Statement covering the waste management options of the post reactor commercial fuel cycle. This Environmental Impact Statement is now being prepared by a large number of people throughout the country under the general coordination of Carl Unruh of the Battelle Northwest Laboratories. It will be published in draft form in the spring of next year at which time comments will be requested in accordance with NEPA procedures.

While preparing for the Denver symposium, we received suggestions from a variety of sources that there were a number of social and economic phases of radioactive waste management which might not fit into a basically technical symposium, but which would merit exploration in a public meeting. This was obviously a good suggestion, and it seemed equally obvious that ERDA should not be the only Federal agency interested in such a meeting. The positive reaction of other agencies to this idea resulted in the present jointly sponsored meeting. On behalf of the ERDA Division of Nuclear Fuel Cycle and Production, I would like to add my welcome to those already expressed.

The TAD document and the Denver meeting hopefully provide a technical background so the discussions of the next three days can take place with common understanding of the options provided by technology and the limitations imposed by nature. Many of the subjects to be discussed here will impact on the Generic Environmental Impact Statement preparation and as a result the team working on that statement are well represented in this audience as very interested listeners. While technological considerations must define the basic options available, it is equally true that, particularly in the case of a subject like radioactive waste management, social, economic, environmental and other public policy issues are of cardinal importance. I would like to assure you that the public policy issues are considered by ERDA to be inseparable from the technical issues in our waste management programs.

As an introduction to the discussions of the next three days, I should like to summarize the ERDA commercial waste program. I will treat the subject in rather general terms since the next speaker, Mr. John Bartlett, is going to deal in more detail with technology of waste management.

The ERDA decision last year to propose a major revision in the level of effort in waste management program was approved by the Administration and made public in the President's budget proposal to Congress for Fiscal Year 1977. The first slide shows in gross form the magnitude of this initiative. The 1977 proposed budget totaled $90 million for commercial and defense waste compared to a Fiscal Year 1976 level of just under $31 million--an increase by a factor of three. The increased emphasis on the commercial waste is even more dramatic--a factor of five. In the appropriations process, Congress added $5.6 million to the proposed budget, and the modified appropriation bill has been signed by the President.

It seems reasonable to infer from these budget actions that Congress shares the determination of the Administration that the waste problem be decisively attacked now. As further evidence of the Administration's interest in decisive action, a statement[2/] of the Energy Resources Council was presented to a committee of Congress last May in which contained a coordinated timetable involving six agencies of the Federal Government leading to a national repository for high-level radioactive waste in 1985. Of the agencies sponsoring this meeting, CEQ and EPA were cosponsors of the ERC report.

The review of the status of waste management technology documented in TAD concluded that basic technology was available for processing and disposing the waste streams from the fuel cycle. Application development was necessary in several cases to provide practical processes; for example, solidification of high-level wastes, treatment of hulls and transuranic waste. Further, a repository for high-level and transuranic waste must also be constructed applying the available basic technology.

The present ERDA waste management program consists of three parts:

1. Terminal storage - development of a repository for waste.
2. Waste processing - development of technology for the conversion of all forms of radioactive waste into a suitable form for packaging, transporting and final disposition.
3. Preparation of Generic Environmental Impact Statement - systematic evaluation of the environmental impact of alternative methods for dealing with the various streams from the back end of the fuel cycle.

The pending GESMO decision by the Nuclear Regulatory Commission as to whether plutonium recycle will be permitted obviously influences the type of waste management technology required. If a negative GESMO decision results in a decision by industry not to process spent fuel, the fuel elements themselves may become waste. The ERDA commercial waste management program provides for both options--reprocessing or no reprocessing. Similarly, the Generic Environment Impact Statement treats both options.

ERDA's basic approach to the handling and storage of radioactive waste involves a concept of multiple barriers between the waste and man's environment. (Slide 2) High-level radioactive waste will be converted from a liquid into a stable solid form and sealed in a high-integrity container. In this state the waste is in a safe form for shipping and handling and should maintain its integrity for many years. The encapsulated waste will then be placed in a deep stable geologic formation. (Slide 3) Geologic formations, such as salt beds, which have been in existence for hundreds of millions of years can provide the final containment of the waste and isolation from man for the approximately quarter of a million years required for decay of the waste. Note that the extremely small extrapolation of the known history of the formations necessary to accommodate even the decay of the plutonium is shown on the chart by the width of the line separating the past from the future. Incidentally, if one considers the level of hazard to mankind and the environment already present in the form of natural pitchblend deposits as acceptable, it is quite possible that the length of time involved may be less than a thousand years.[3]

Since the ERDA geologic approach to waste isolation is directed to repositories in locations free of pathways to the biosphere, no special dependence on the natural capacity of soils to retain plutonium and fissions products is involved. It is interesting to reflect that a much more dramatic waste isolation problem than presented by the fuel cycle was apparently solved by nature on its own without any engineering assistance from man. I refer to the "Oklo Event" which occurred over 1.8 billion years ago when a rich uranium deposit in an area that is now the Oklo Mine in the Republic of Gabon, Africa, became the location of natural nuclear reactors lasting for thousands of years. As a result of the nuclear chain reaction, metric ton quantities of transuranics and fission products were produced. By carefully examining the region surrounding the criticality event, it has been found that plutonium and most of the fission products were essentially contained within the formation. Of course, the data from Oklo is only valid for this particular type of geology, geochemistry, and climatic conditions, but if similar events in other formations are found, important additional data points would be provided for further insight into plutonium and fission product migration through soils over geologic time periods. I might add that the lack of migration at Oklo was consistent with predictions made from basic understanding of the chemistry and migration mechanisms of these waste products in soils. This Oklo event is described in the July issue of Scientific American.4/

Emplacement in geologic formations was identified as the most practical, environmentally satisfactory disposal method for high-level and transuranic wastes after the alternatives of emplacement into the seabed, ice sheet disposal, and partitioning followed by either transmutation or extraterrestrial disposal were found not to offer promise for application within the next decade.

The geologic disposal option has been under study in this country with varying intensity since about 1958 and the present ERDA program is based upon that background. Furthermore, this concept has been carefully investigated by two special committees of the National Academy of Sciences and given strong support. This support was formally illustrated recently by the very strong testimony of Dr. John Frye, previous chairman of the NAS Committee on Radioactive Waste Management, at the McCormick subcommittee hearings of the Joint Committee on Atomic Energy on May 11 of this year.

Three types of geologic formations are believed to be satisfactory for a repository--salt, crystalline rock (such as granite or basalt) and the argillaceous rocks (such as shales). Some 45 of the contiguous 48 states are associated with at least one of these major formations.

The ERDA terminal storage program provides for the development of sites for six repositories with the first two repositories available for receiving waste in 1985. Because of the extensive experience with salt in the past AEC program, the first two repositories are planned for salt. The four following repositories are expected to be in both crystalline and argillaceous rocks. Suitable formations of each type are now known so that basic thrust of the program is the location of suitable local examples of the formation free of local defect, e.g., appropriate depth, free of circulating water with potential for reaching the biosphere, free of major cracks, appropriate seismic prospects, etc.

When completed, the repository would consist of a large number of excavated rooms located thousands of feet below the surface of the ground. On the surface would be located receiving and handling facilities for containerized solid waste or spent fuel which would be delivered by truck or rail. The surface facilities would occupy approximately one hundred acres and be the only visible evidence of the repository. The subsurface excavation for a full-scale facility might occupy a land area with a radius of about one mile. Surface areas above the excavation, but outside the fence around the surface facilities, could be leased for general land use. Surrounding the central excavated area would be an outer controlled area with a radius of about four miles in which deep drilling would be controlled to avoid any compromise of the long-term security of the repository. Land over the outer controlled area would probably not be restricted from normal usage.

These repositories when they are initially opened will be designed and operated in a way that permits waste to be removed as easily as it is emplaced if unexpected events should indicate the repository is unsatisfactory. I want to emphasize that the repository as constructed will be expected to be a permanent disposal place for the waste and the retrievability feature is to be exercised only if the unexpected occurs.

The repositories will be subject to the licensing and other regulatory authorities of the Nuclear Regulatory Commission. Hence, we anticipate that the retrievability feature of the early phase of the repository will be one of several license conditions imposed by the NRC. Removal of these license conditions will, of course, be subject to such conditions as imposed by them.

In addition to the independent review of each high-level waste repository which the Nuclear Regulatory Commission licensing mechanisms will provide, the ERDA program provides for close and continuing state involvement during the progress of the work. This state participation could be by one or more state agencies, or it might be through a special committee such as is functioning in New Mexico in connection with the Carlsbad project. ERDA is depending on discussions and reviews with state authorities beginning with the early screening of possible formations and sites to assist in the design and execution of the program. We expect intense local interest in the program and a special effort will be made to adequately inform and consult with the concerned public.

In addition to a repository for waste, processes are required to convert the various waste streams from the post reactor fuel cycle into chemical and physical forms suitable for transportation and emplacement into a final disposal facility. Unlike terminal storage, the product of this part of the ERDA program is technology for the adoption by industry at their initiative.

The 1975 ERDA review of waste management technology clearly identified solidification of the high-level waste stream from reprocessing plants as by far the most critically needed process development requirement. While basic technology was found satisfactory, application development was clearly necessary. It is generally agreed that the product from a solidification process should be chemically and radiolytically stable and at least in its packaged form should retain a monolithic characteristic on impact.

The solid and its container clearly must last for the period of transportation and emplacement and further, for such time as the repository is operated in a retrievable mode.

Considerable characterization of the various candidate solid waste forms has been done. The data obtained must now be used for formal hazard analysis studies by both ERDA and the Nuclear Regulatory Commission. These analyses have been started by ERDA and will be continued in the present program. At least preliminary regulatory guidance is expected from NRC by the end of this year.[5]

A variety of potential solidification processes are now available from former AEC work. A unit producing a borosilicate glass product from a spray calciner has been successfully operated with hot simulated commercial waste at a rate which would have been sufficient to handle the waste from the Nuclear Fuel Services reprocessing plant before it was shut down for expansion. The calciner part of this process has operated successfully with a simulated waste stream without radioactivity at a rate 60% of that required to accommodate the high-level waste stream from the new Allied General Nuclear Services reprocessing plant at Barnwell, South Carolina. In addition to the spray calciner, a fluid bed calciner process is in a similar state of development.

While borosilicate glass is receiving early prominence in the hot pilot plant program, other waste forms will continue to be investigated. It is likely that more than one waste form may meet the eventually established criteria for terminal storage.

Examination of technology for handling waste streams other than high-level generally found acceptable, commercially procurable hardware and processes. Two areas were identified where the incentive for methods of greater efficiency was sufficiently great to receive special emphasis in the ERDA program. These are methods for reducing the volume of hulls from the head-end step of the reprocessing plant and methods for reducing the volume of transuranic-contaminated combustible waste. The ERDA program supports work on several improved processes for handling each of these waste streams.

Obviously, if a negative decision by the Nuclear Regulatory Commission on plutonium recycle should result in a decision by American industry not to reprocess fuel, the fuel elements themselves would become waste. A technique for emplacement and retrieval of fuel elements in a repository was demonstrated in a general way as long ago as 1960 in connection with Project Salt Vault. Compared to the solidification of liquid waste from a reprocessing plant, little more processing type R&D is required.

In addition to the research and development program for commercial radioactive waste, the FY 77 Presidential budget numbers indicated a large increase in the program for radioactive wastes from the U.S. military program, with emphasis on the permanent disposition of the large backlog of the latter wastes. While this program per se is outside the scope of this meeting, we do expect that some of the developments originating in the defense waste programs will be applicable to commercial waste and vice versa.

Both programs are structured to exploit this possibility. As an example, a promising bedded salt formation in southeastern New Mexico is being investigated as a site for construction of a pilot repository for permanent disposition of transuranium-contaminated solid waste from the military program. This repository will also have experimental capability to look at the suitability of the formation for high-level radioactive waste. As another example, a development facility has recently been completed at Los Alamos for the incineration of tranuranium waste generated at that site. This work should be directly applicable to commercial fuel cycle plants.

Before leaving the subject of ERDA's waste program, I would like to say a few words about programs outside the United States. Waste management programs in Europe are also receiving major national emphasis. The similarity of approach here and abroad to both waste processing problems and to terminal storage is striking. West Germany is conducting extensive investigations in bedded salt for a high-level repository. Further, they are the only western nation with a pilot disposal site in a salt mine currently operating with low-level waste. France is considering deep clay formations as possible waste disposal locations, while Canada and Sweden are studying granite formations. These countries, in addition to others which are starting similar programs, are exchanging geologic, scientific and engineering data in order to aid one another in solving these problems. The United States has access to all of these programs and our data is being utilized by other countires.

What is the magnitude of the high-level waste problem? Most of the commercial high-level waste has yet to be generated. At this time, all of the high-level waste generated to date in the United States consists of 600,000 gallons of liquid waste stored in modern tankage at the NFS facility outside Buffalo, New York. Since no reprocessing plant is operating, no further high-level waste is being produced. None will be produced until either a reprocessing plant begins hot operation or utilities declare spent fuel to be waste. A typical 1000 Megawatt (electrical) reactor will eventually be responsible at the fuel reprocessing plant for about 65 cubic feet of solidified high-level waste per year. The accumulated volume of high-level waste from power reactors through the year 2000 has been estimated as equivalent to a cube 72 feet on a side. This is obviously not an overwhelming volume problem and there appears to be well justified reasons for expecting that the important isolation problem will be solved by deep geologic repositories.

The expansion of nuclear power demands resolution of the waste disposal issue. The provision of a demonstrable safe, environmentally acceptable terminal disposal method for high-level waste in the earliest practical time period is a necessary step in securing public acceptance of nuclear power. A firm plan and commitment to this end is essential.

A national program has been conceived by the Administration and supported by Congress to decisively attack the waste management problem. The major ERDA program beginning this month comprehensively addresses all of the waste problems identified with the post reactor part of the fuel cycle. Process capability will be developed for the use of private industry to convert each of the various waste streams into forms in which they may be safely transported and terminally stored. A number of areas of the United States have been identified as underlain by geological formations with the properties desired for a terminal repository. The scheduled program, assuming continuation of the momentum of the 1977 budget, provides an excellent prospect of having several repositories constructed in time to receive waste when it must be shipped by commercial processing facilities. Finally, improved communications are planned with State, local and regional officials and members of the general public to maximize the chances of this vital program being understood and accepted on both technical and nontechnical bases. ERDA is now developing methods whereby the States, industry and others can assist in a meaningful way the development of an operational plan for commercial waste management which will meet the national needs.

In bringing these remarks to a conclusion, I should like to return to my earlier point that technical issues and public policy issues are not entirely separable. Over a period of years, the United States Congress has prefaced many statutes with "legislative findings." Among these many findings are that there should be full productivity and full employment;

that the peaceful uses of atomic energy can and should be developed; and that the environment should be protected. The translation of these findings into practical actions obviously takes a bit of doing. We in ERDA recognize that we have the technical responsibility for any radioactive waste which must go to Federal custody. However, technical responsibility does not also mean a monopoly on wisdom, especially wisdom in areas of public policy. No responsible person in ERDA believes for a second that we can or should operate the commercial waste program behind closed doors. We need and want the views and suggestions of those of you in other agencies, in environmental groups, in industry, in unions, in the academic community, and those not in any special group at all--the proverbial average citizen. One means of expressing these views will be through comments and hearings on the generic environmental statement on commercial waste management, and there will be others. ERDA representativ will be on hand throughout the present meeting to listen carefully to the discussions. I would like to close by suggesting as a thought for the remainder of the meeting that it is going to take careful, responsible thinking, communicated in a careful, responsible manner, with strong emphasis on positive solutions, on the part of all of us if our national goals are to be met. Thank you.

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2. "Management of Commercial Radioactive Nuclear Wastes - A Status Report", published by Federal Energy Resources Council-CEQ, Department of Commerce, U. S. Geological Survey, Environmental Protection Agency, Energy Research and Development Administration, Federal Energy Administration, May 10, 1976.
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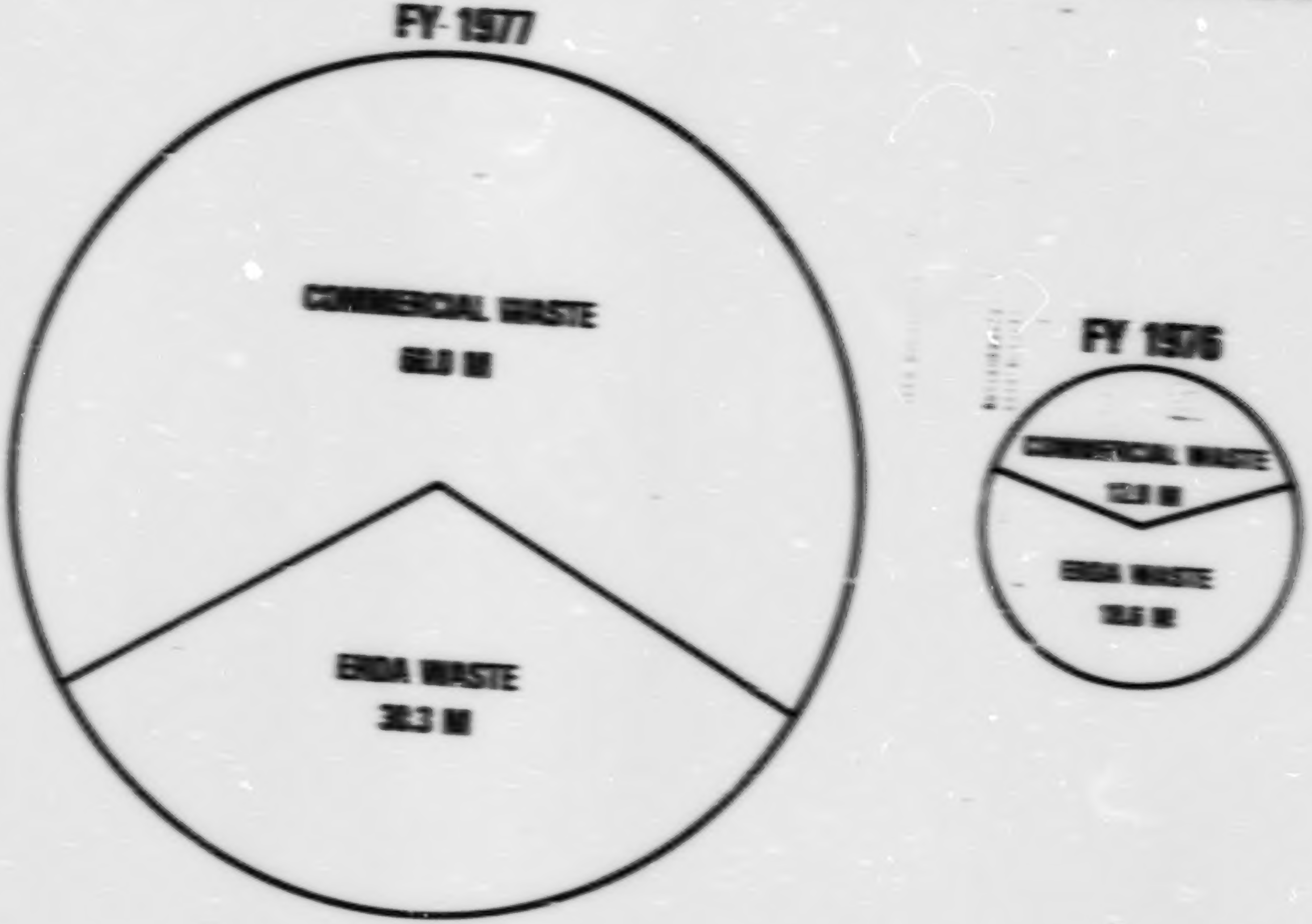
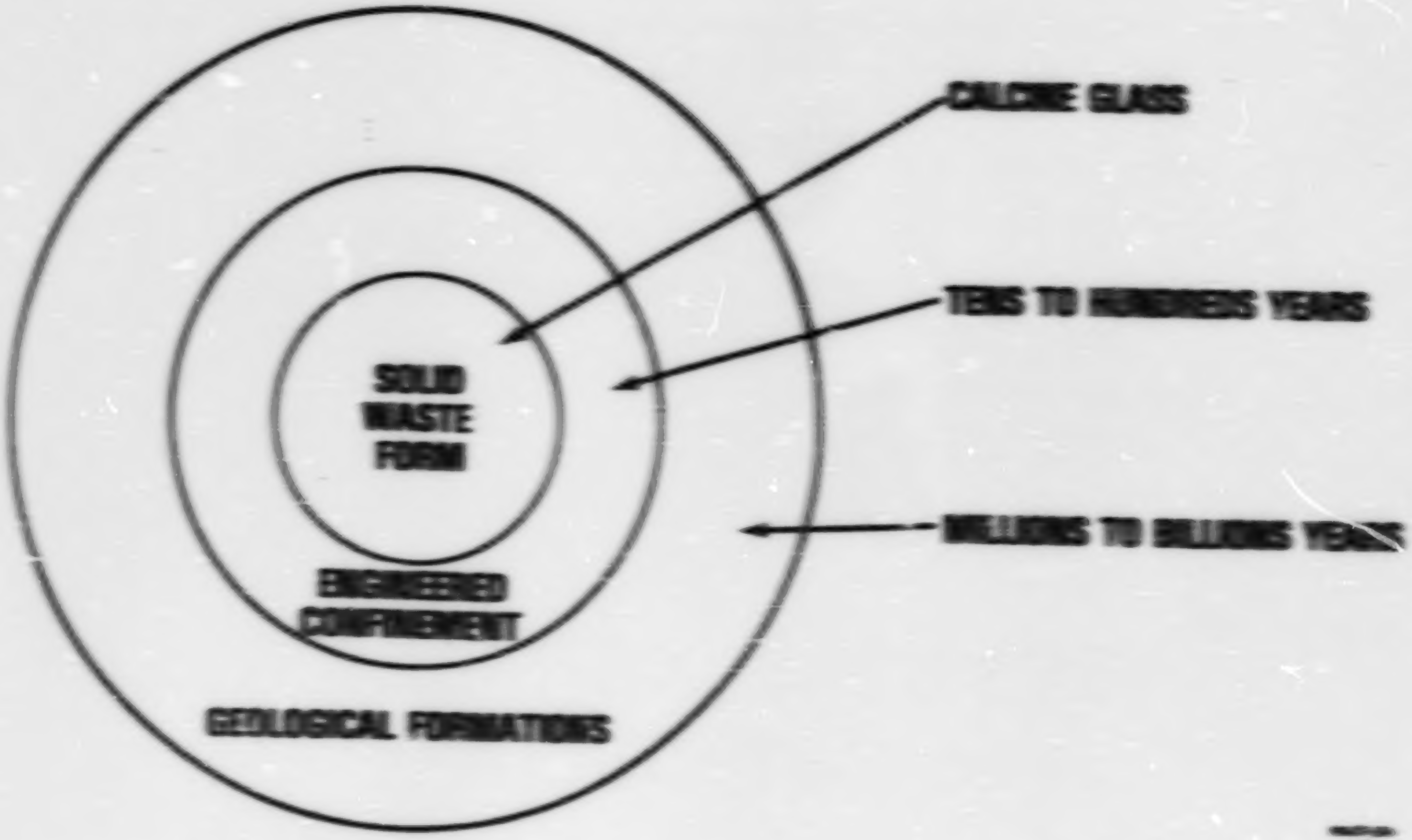
WASTE MANAGEMENT OPERATING BUDGET



Slide 1

BARRIERS TO THE ENVIRONMENT



SOLID
WASTE
FORM

ENGINEERED
CONFINEMENT

GEOLOGICAL FORMATIONS

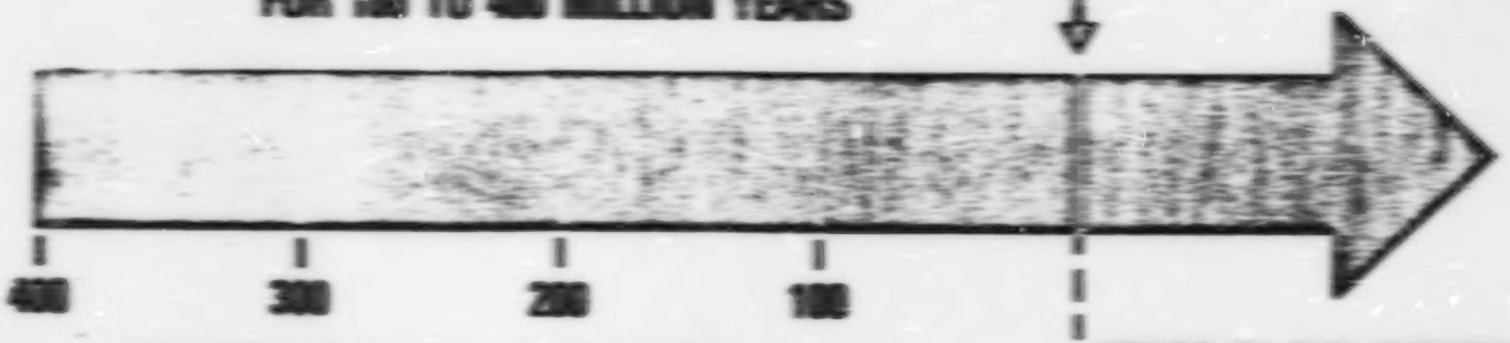
CALCINE GLASS

TENS TO HUNDREDS YEARS

MILLIONS TO BILLIONS YEARS

Slide 2

TIME SCALES FOR GEOLOGIC STORAGE



240,000 YEARS-
PLUTONIUM DECAYS
TO 1/1000th

SALT DEPOSITS HAVE BEEN IN PLACE
FOR 100 TO 400 MILLION YEARS

400
300
200
100

MILLIONS OF YEARS IN THE PAST

YEARS IN THE FUTURE

ALTERNATIVES FOR MANAGING POST-FISSION NUCLEAR WASTES

By

A.M. Platt and J.W. Bartlett
Battelle, Pacific Northwest Laboratories
Richland, Washington 99352

ABSTRACT

The major nuclear waste management operations involved in the back end of the LWR fuel cycle include interim storage, treatment, and transportation. The wastes can include spent fuel, fuel cladding and hardware, high-level and various combinations of fission product and/or transuranic contaminated liquids, combustible and noncombustible solids.

The technologies for management of wastes from the reactors, wastes from facilities used in the back end options, and wastes produced by decommissioning fuel cycle and waste management facilities are described. Technologies being developed or used by other nations are included.

Technologies are classified as commercialized, available, or under development. Commercialized technology is that in routine use within a nuclear industry. Technology is classified as available if design, construction, and verification could be initiated with reasonable technical risk based on present knowledge. (This should not be interpreted to mean that parallel efforts might not be required to obtain additional information on process technology or to verify design details.) Technologies under development range from new concepts just starting into R&D to those nearly available.

Commercial or available technologies are shown to exist for essentially all the operations required to manage the nuclear waste created by the back end or post-fission LWR fuel cycle.

ALTERNATIVES FOR MANAGING POST-FISSION NUCLEAR WASTES

This paper presents an overview and synopsis of the alternatives from the back end of the commercial LWR fuel cycle. The basis for the information is the so-called technical alternatives document (TAD) published as ERDA 76-43.(1) It is available from the National Technical Information Service, Springfield, VA 22161. Approximately two hundred professionals participated in writing the document.

The basic scope of TAD includes:

- Overview characterization of three alternative fuel cycle and waste management systems:
  Operation without fuel reprocessing ("throwaway" fuel cycle)
  Recycle of uranium, storage of plutonium, and use of available waste management technology.
  Recycle of uranium and plutonium; use of available waste management technology.
- Identification and characterization of wastes from the back end of the commercial LWR fuel cycle.
- Projection of waste quantities.

The alternative waste management technologies are discussed in terms of four basic waste management activities:

- Treatment, which converts the wastes from their as-generated form to forms needed for handling, transportation, and final disposition of the wastes. As-generated wastes are termed "primary wastes"; wastes that emerge from treatment operations are "secondary wastes."
- Interim storage, which provides retention of primary and secondary wastes while they are in man's environment and subject to subsequent management activities such as treatment or transportation.
- Transportation, which is applied to movement of waste materials between sites.
- Final isolation or disposal, which provides final disposition of wastes. The basic alternatives are isolation in geologic media or elimination of the wastes from existence on earth.

We identify three technology classifications: commercialized, available, or under development. Commercialized technology is in routine use in the nuclear industry. Technology is said to be "available" if design, construction, and verification testing of full-scale commercial facilities can be initiated on the basis of present knowledge. Technologies under development range from early-on concept testing in the laboratory to nearly available. These technologies anticipate benefits such as reduced environmental impacts, simplified procedures, and reduced costs but are unproven and unavailable.

FUEL CYCLE OPERATIONS

Characteristics and quantities of wastes produced in the back end of the LWR fuel cycle will depend on technologies and logistics used for fuel cycle and waste management operations. Overview characterizations were developed for three basic alternatives, each of which was assumed to use available waste management technology:

- No recycle of uranium or plutonium
- Uranium recycle only (plutonium is stored)
- Recycle of uranium and plutonium.

Waste management requirements for these alternatives differ in detail. The two recycle options are, within the framework of assumptions used, similar with respect to impacts on waste management: both require fuel reprocessing and its comparatively strong impact on waste quantities and characteristics. Recycle of plutonium in addition to uranium involves addition of mixed-oxide fuel fabrication plants to the fuel cycle; such operations have minor effect on waste quantities. The "throwaway" fuel cycle (no recycle of plutonium or uranium) minimizes waste quantities but maximizes inventories of long-lived alpha particle-emitting nuclides in the wastes. Detailed comparative assessments of these alternatives have not been made and are not within scope of the TAD document.

Figure 1 summarizes some of the information on the types, quantities, and activities of the wastes produced by a fuel cycle reutilizing both plutonium and uranium.

The principal effects of the fuel cycle operational mode on waste management are shown in Table 1. Perhaps the most significant factor is an increase in actinide content by a factor of 50 in spent fuel as compared to that in the wastes from a closed cycle.

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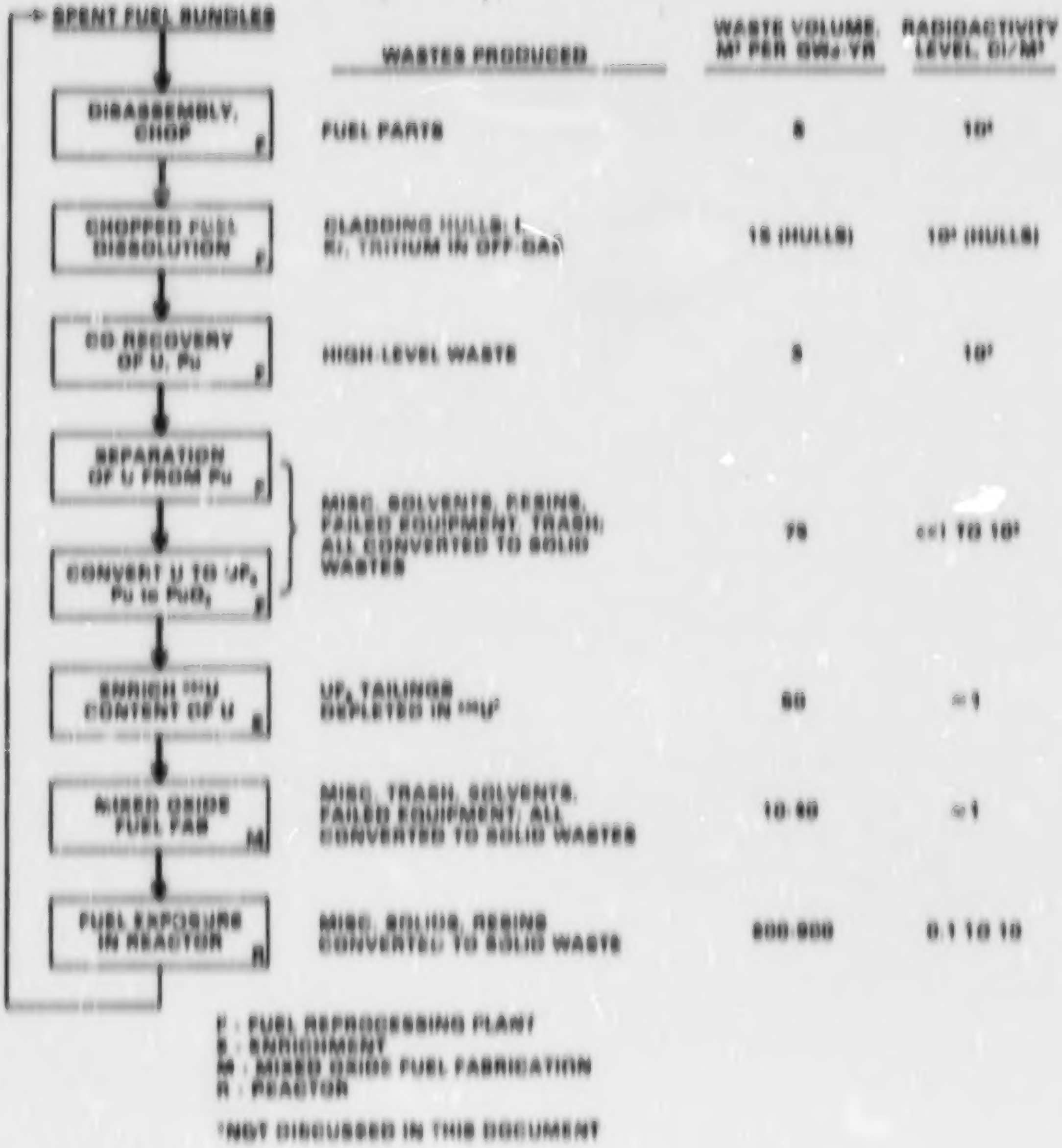
SPENT FUEL BUNDLES
WASTES PRODUCED
WASTE VOLUME, M³ PER GWe-YR
RADIOACTIVITY LEVEL, CI/M³
DISASSEMBLY, CHOP F
FUEL PARTS
5
10³
CHOPPED FUEL DISSOLUTION F
CLADDING HULLS; I, Kr, TRITIUM IN OFF-GAS
15 (HULLS)
10⁴ (HULLS)
CO RECOVERY OF U, Pu F
HIGH-LEVEL WASTE
5
10⁷
SEPARATION OF U FROM Pu F
CONVERT U TO UF₆ Pu to PuO₂ F
MISC. SOLVENTS, RESINS, FAILED EQUIPMENT, TRASH; ALL CONVERTED TO SOLID WASTES
75
<<1 TO 10³
ENRICH ²³⁵U CONTENT OF U E
UF₆ TAILINGS DEPLETED IN ²³⁵U*
50
≈1
MIXED OXIDE FUEL FAB M
MISC. TRASH, SOLVENTS, FAILED EQUIPMENT; ALL CONVERTED TO SOLID WASTES
10-50
≈1
FUEL EXPOSURE IN REACTOR R
MISC. SOLIDS, RESINS CONVERTED TO SOLID WASTE
200-800
0.1 TO 10
F : FUEL REPROCESSING PLANT
E : ENRICHMENT
M : MIXED OXIDE FUEL FABRICATION
R : REACTOR
*NOT DISCUSSED IN THIS DOCUMENT

FIGURE 1. Process Operations and Wastes in the LWR Fuel Cycle

TABLE 1. LWR Fuel Cycle Comparison

	Clad + High-Level Waste	Discard Fuel
Mass, MT/GWe yr		
Plutonium	0.006	0.35
Uranium	0.20	43
Total	16	65
Heat, kW/GWe yr		
1 yr cooled	350	410
10 yr cooled	60	40
Activity, MCi/GWe yr		
1 yr cooled	75	100
10 yr cooled	10	15
Self-Fission 10^9 neutrons/GWe/yr		
1 yr cooled	160	4
10 yr cooled	110	2.5

We consider now the status of technology for the four basic waste management activities identified earlier, i.e., treatment, interim storage, transportation, and final isolation or disposal of the various types of wastes.

IRRADIATED FUEL

The technology is available and in use for interim storage and transportation of irradiated LWR fuel. If the irradiated fuel becomes a waste, i.e., if the uranium and plutonium in spent fuel are not returned to the fuel cycle, then the fuel assemblies can be stored or managed as a waste, e.g., by placing them in containers and filling the void space with metal. Such technology is available but has not been used.

CHOP-LEACH FUEL BUNDLE RESIDUES

The chop-leach fuel bundle residues are solid wastes comprising short lengths of fuel cladding, fuel bundle support rods, poison rods, massive end fittings, fuel support grids, assorted springs, and spacer elements. Between 0.05 and 0.5% of the original fuel material remains with these wastes as an insoluble residue. The available technology is to store these wastes without treatment. The small amount of chop-leach bundle residue wastes generated in the U.S. to date, at the Nuclear Fuel Services Plant, was packaged in steel containers and placed in shallow geologic isolation (burial grounds).

Advanced technology is being developed to decontaminate and/or consolidate these wastes by mechanical compaction, by melting, or by chemical reaction.

HIGH-LEVEL WASTE

Table 2 shows the many technologies to treat the high-level liquid waste. This treatment operation has received intensive development throughout the world. Most of these developments are now aimed towards the production of silicate glasses as the primary product.

Most of the processes are considered ready or available for commercialization. The remaining minor technical questions can be answered in parallel with the design/construction activities.

TABLE 2. High-Level Waste Immobilization

Product Concept	Concentrator		Calciner		
	None	Other	Rotary Kiln	Fluid Bed	Spray
Calcine			US-BNL	US-INEL US-GE	
Glass In-Can	Harvest Fingal UK	Drum Drier Pamela FRG	US-PNL	US-PNL	
Glass Metallic Melter	Piver France	Phosphate US-BNL	AVM France		VERA FRG
Glass Ceramic Melter		Wiped Film US-PNL			
Metallic Matrix				Stirred bed Lotes FRG/Belgium	Coated Pellets US-PNL

COMBUSTIBLE SOLIDS

The basic treatment options available for combustible solids are shown in Figure 2. In most cases the preferred path is to combust or oxidize the waste to reduce its volume and ignition capability.

Combustible solid radioactive wastes include a large variety of items such as paper, rags, plastic sheeting, protective clothing, gloves, rubber shoes, wood, organic ion exchange resins, filter aids, etc. Much of the waste material is collected as general trash, which usually consists of a mixture of combustible and noncombustible items. Therefore, treatment options generally include sorting prior to treatment of the wastes.

A wide range of combustion/oxidation technologies are available.

NONCOMBUSTIBLE SOLID WASTES

Figure 3 shows the options available for treatment of noncombustible solid waste. There is no sharp line of distinction between technologies available and those requiring further development. In most cases, the required development is the engineering necessary for the technique to be employed in radioactive service.

The primary constituent of these solid wastes is metal, but other noncombustibles such as glass and concrete are also present. Incidental quantities of combustible material such as grease, plastic, and floor sweepings can also be included with the noncombustible waste.

Most failed or obsolete process equipment eventually becomes noncombustible waste. It is normally flushed and decontaminated prior to removal from service and has combustibles removed wherever it is practical to do so. Typical large items from a fuel reprocessing plant may consist of dissolvers, columns, and concentrators which might be up to 3 meters in diameter and 10 meters in height. Disassembly may be required for movement beyond the confines of the reprocessing facility. Such wastes are typical of decommissioning operations.

IMMOBILIZATION OF NON-HIGH-LEVEL WASTES

Essentially all of the treatment processes just described for liquids and solids result in dispersable liquid concentrates or solids.

Many alternatives exist to immobilize these wastes. Without going into process detail, Table 3 lists the principal technologies.

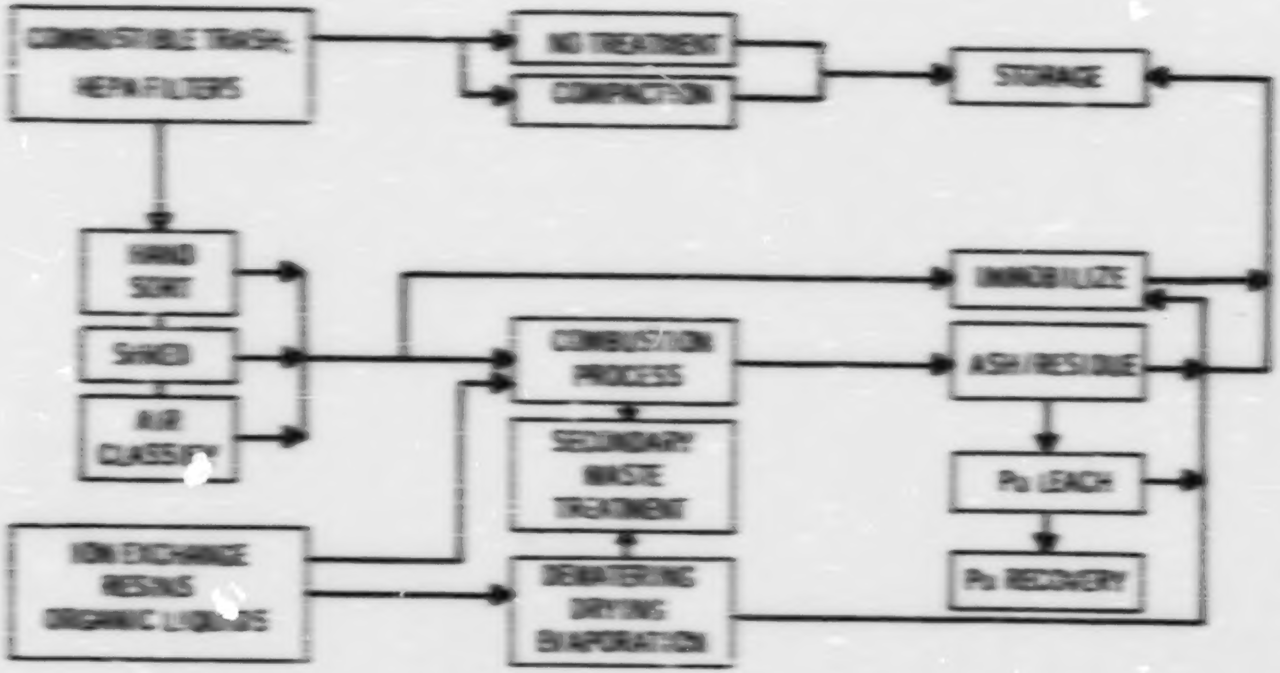
COMBUSTIBLE TRASH;
HEPA FILTERS
NO TREATMENT
COMPACTION
STORAGE
HAND SORT
SHRED
AIR CLASSIFY
ION EXCHANGE RESINS
ORGANIC LIQUIDS
COMBUSTION PROCESS
SECONDARY WASTE TREATMENT
DEWATERING DRYING EVAPORATION
IMMOBILIZE
ASH/RESIDUE
Pu LEACH
Pu RECOVERY

FIGURE 2. Treatment Options for Combustible Radioactive Wastes

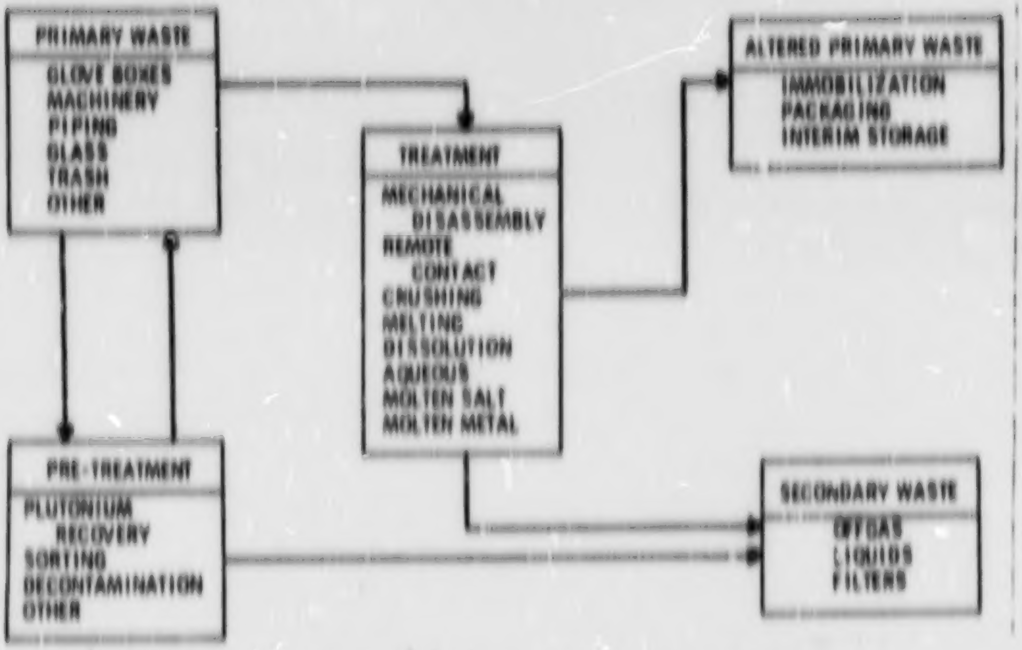
PRIMARY WASTE
GLOVE BOXES
MACHINERY
PIPING
GLASS
TRASH
OTHER
TREATMENT
MECHANICAL
DISASSEMBLY
REMOTE
CONTACT
CRUSHING
MELTING
DISSOLUTION
AQUEOUS
MOLTEN SALT
MOLTEN METAL
ALTERED PRIMARY WASTE
IMMOBILIZATION
PACKAGING
INTERIM STORAGE
PRE-TREATMENT
PLUTONIUM
RECOVERY
SORTING
DECONTAMINATION
OTHER
SECONDARY WASTE
OFFGAS
LIQUIDS
FILTERS

FIGURE 3. Noncombustible Solid Waste Flow Diagram

TABLE 3. Immobilization Alternatives

TECHNOLOGIES IN USE	TECHNOLOGIES UNDER DEVELOPMENT
Absorbents	Aluminosilicate Minerals (Clay)
Salt Matrix	Glass/Ceramics
Urea-Formaldehyde Resins	Pelletization/ Compaction
Cement/Concrete	Polyethylene and Other Organic Polymers
Bitumen (Asphalt)	Metal Matrix

The technologies under development are designed primarily to improve the leach resistance of the solidified products. Foremost in this field are the vitrification processes which yield glass products with leach rates of 5×10^{-6} g/(cm^2-day) or less for the more leachable components. Pelletization processes produce ceramic or cermet pellets which should have equally high leach resistance. The leach resistances of polyethylene products are comparable to those for bitumen products, while the leach resistances of the aluminosilicate mineral salt-fixation products are approximately comparable to those for cement products. The leach rates for rare-earth and actinide elements are several orders of magnitude lower than the leach rates for alkali and alkaline-earth elements.

GASEOUS WASTE

The current generation of reprocessing plants releases krypton-85 and tritium and recovers iodine-131 and -129. Consideration is currently being given to whether or not this practice should be or needs to be changed. However, technical work on all three gaseous wastes is underway, primarily because of potential need in non-LWR fuel cycles. A summary of this work is shown in Table 4. Technology is available for capture of krypton and iodine, but further development is required for tritium.

INTERIM STORAGE

The basic options that exist for interim storage are shown in Table 5. Considerations such as radiation levels, heat generation rates, and allowable temperature limits are key factors in the selection of the most appropriate packaging and interim storage technology for a particular waste. The most practical and effective choice among the many basic interim storage alternatives is to minimize the number of packaging, handling, and transportation steps between generation of the waste and terminal storage.

GEOLOGIC ISOLATION

Most of the nations now using nuclear power are considering geologic isolation as the means for final disposition of commercial nuclear power wastes. The other basic option for final disposition is to eliminate the isotopes from existence on earth. This might be done by extraterrestrial ejection or by transmuting the isotopes into other elements. At present, however, there is no practical technology for these elimination options.

TABLE 4. Gaseous Waste Treatment

IODINE	
Caustic Scrubbing	Technology Available
Mercuric Nitrate Scrubbing	Technology Available
Nitric Acid Scrubbing - Iodox	Technology Under Development
Chemisorption	
Silver Loaded	Technology Available
Metal Loaded	Technology Under Development
KRYPTON	
Cryogenic Distillation	Technology Available
Liquid Fluorocarbon	Technology Under Development
TRITIUM	
Voloxidation	Technology Under Development
Pyrochemical	Technology Under Development

TABLE 5. Interim Storage Alternatives

Storage Alternative	Heat Removal	Corrosion Control	Maintenance Requirements
Water Basin	Forced Circulation of Basin Water	Packaged in Inert or Noncorrosive Medium	High
Air-Cooled Vault	Natural Circulation of Air	Packaged in Inert or Noncorrosive Medium	Low
Concrete Surface Silo	Natural Circulation of or Conduction to Air	Packaged in Inert or Noncorrosive Medium	Low
Near-Surface Heat Sink	Conduction to Earth	Packaged in Inert or Noncorrosive Medium	Low

Four candidate geologic isolation environments can be identified: sediments or basement rock of the sea floor, ice sheets, shallow continental geologic formations, and deep continental geologic formations. The focus of effort throughout the world is to use deep geologic formations within national borders to isolate high-level and other transuranic wastes. Low-level and nontransuranic wastes would be placed in shallow geologic formations (burial grounds) or the sea floor.

The United States (contiguous 48) has numerous geologic formations that are potentially suitable for deep isolation of transuranic wastes. These include the Michigan and Permian basins (bedded salt), the salt domes of the Gulf Coast region, and igneous rock formations in the north central and northwestern states. The various formations are described in Volume 5 of ERDA-76-43.

The process of selecting a site for a geologic repository is one of proceeding from the general to the specific. The formations cited above are generally suitable; through a process of geologic characterization and evaluation of other factors such as ecology, climate, availability of services, etc., site-specific candidate repository locations will be identified. System designs reflecting the characteristics of the candidate site and the wastes to be emplaced would then be developed and evaluated. Emplacement of wastes into the geologic formation would be expected to be accomplished using conventional mining technology.

A major part of evaluating a geologic repository concept is aimed at consideration of maintaining long-term isolation of the wastes. The process actually starts with the site selection procedures since the particular site is selected on the basis of past stability and expected future stability of the geology. Basic geologic stability must be anticipated (e.g., freedom from faulting or water intrusion) or a site will not be a candidate for a repository.

Evaluation and design to assure long-term maintenance of waste isolation go beyond selection of highly stable geologic formations. One concept used is that of multiple barriers between the waste and the biosphere. The first such barrier is the waste form itself, selected to be highly resistant to degradation and leaching. The second barrier is composed of engineered structures (e.g., waste canister containers or vault liners), if used, between the waste form and the surrounding geology, which serves as the third barrier. Loss of isolation would then require that disruption of all barriers occur in such a manner that pathways and mechanisms to transport the wastes from the repository to the biosphere are created.

Although such disruptions are not expected, studies have been made to estimate the consequences if they should occur. The studies fall into four categories:

- sudden natural events such as meteorite impact
- geologic processes such as faulting or ice ages
- changes in local geology caused by creating the repository and introducing thermal and radiation sources
- human intrusion.

Studies completed in the past are reported or discussed in several documents.(1-4) There have been evaluations in each of the above categories.

Past studies have used evaluation techniques such as risk analysis, probability assessment, consequence analysis, and hazard indices. All results to date show that loss of isolation is highly improbable and/or the consequences are insignificant. Additional evaluations are needed, however, to expand the scope of conditions considered and to provide as much confidence as possible in the validity of results, which can never be subjected to experimental verification. Additional generic studies are under way, and specific evaluations will be made for each candidate repository site.

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Psychological Determinants of Perceived and Acceptable Risk: Implications for Nuclear Waste Management

Paul Slovic

Decision Research

Eugene, Oregon

This paper was presented at the conference on "Public Policy Issues in Nuclear Waste Management;" Chicago, Illinois; October 27-29, 1976.

I. Introduction

My concern in this talk is with the determinants of public response to the risks of nuclear energy in general and nuclear waste management in particular.

The topic is a vital one. Writing recently in the American Scientist, Alvin Weinberg observed:

> As I compare the issues we perceived during the infancy of nuclear energy with those that have emerged during its maturity, the public perception and acceptance of nuclear energy appears to be the question that we missed rather badly. . . . This issue has emerged as the most critical question concerning the future of nuclear energy. (Weinberg, 1976, p. 19)

Given the importance of the topic, one fact stands out--we know very little about the social-psychological factors, the goals, values, criteria, etc., that determine public response to technological risk in general or energy systems in particular. This is less because the problems in this area are tough (which they are) than because the time and effort applied to them has been miniscule. In fact, I know of only one research project directly relevant to the topic of this session, a study at Battelle of "Public Values Associated with Nuclear Waste Disposal" (Maynard, Nealey, Hebert & Lindell, 1976).

In part, this lack of attention results from the fact that scientists and policy makers have only recently become aware of the problems of public response to societal risk. A best-selling book proposes the thesis that technology is advancing much more rapidly than social attitudes, producing a psychological malady called "future shock" (Toffler, 1970). In energy related areas, the problem may be just the opposite. Public opposition to environmental pollution has progressed considerably faster than technology in recent years. Rather than experiencing future shock, we appear to be witnessing a form of "technological lag" in which science and technology have not had time to cope with the demands of advancing public attitudes (Commoner, 1970; Loevinger, 1971).

However, a flurry of recent research activity has provided the beginnings of knowledge about the socio-political dynamics of societal risk taking. What follows is a brief review of that work, organized as follows: It starts with a discussion of the difficulties that human beings have making decisions under conditions of risk. In this section, we question whether the human intellect, having evolved to cope with hazard by means of trial and error, can prevail in a world where error is becoming increasingly costly. With this as background, the next section discusses the perception and evaluation of societal risks. Here, the problem of determining "How safe is safe enough?" is addressed. The third section brings the preceding material to bear on the potential public response to nuclear power and nuclear waste management. In this section, we examine questions such as: What produces the present, vehement, anti-nuclear power sentiment? Will it last? Will it respond to evidence and discussion? Why the polarization of opinion? What will be the reaction to accidents or energy crises?

The final section describes the one directly relevant study to which I referred earlier--a study that attempts to measure values and attitudes pertaining to the waste management problem.

II. Coping Intellectually with Risk

Decisions about nuclear energy require high-level thinking and reasoning on the part of experts and laymen alike. They require an appreciation of the probabilistic nature of the world and the ability to think intelligently about low-probability (but high-consequence) events. As Weinberg (1976) noted, ". . . we certainly accept on faith that our human intellect is capable of dealing with this new source of energy" (p. 31). Recently, however, the faith of those of us who study human decision processes has been shaken.

Consider, for example, probabilistic reasoning. Because of its importance to decision making, a great deal of recent effort has been devoted to understanding how people perceive and process the probabilities of uncertain events. By and large, this research indicates that intelligent people systematically violate the principles of rational decision making when judging probabilities, making predictions, or otherwise attempting to cope with probabilistic tasks. Frequently, these violations can be traced to the use of judgmental heuristics, mental strategies which allow people to reduce difficult tasks to simpler judgments (Tversky & Kahneman, 1974). These heuristics may be valid in some circumstances, but in others, they lead to biases that are large, persistent, and serious in their implications for decision making.

Availability Bias

This is not the place to pursue a full discussion of heuristics and biases in probabilistic thinking. Extensive reviews are available in articles by Slovic, Kunreuther and White (1974), Slovic, Fischhoff and Lichtenstein (1977) and Tversky and Kahneman (1974). However, one heuristic bears mention here because of its special relevance to energy decisions. This is the "availability heuristic" whereby an event is judged likely or frequent if it is easy to imagine or recall relevant instances. In reality, instances of frequent events are typically easier to recall than instances of less frequent events, and likely occurrences are easier to imagine than unlikely ones. Thus availability is often an appropriate cue for judging frequency and probability. However, since availability is also affected by numerous factors unrelated to likelihood, reliance on it may lead to overestimation of probabilities for recent, vivid, emotionally salient, or otherwise memorable or imaginable events.

The notion of availability is potentially one of the most important ideas for helping us understand the distortions that occur in our perceptions of risk. For example, in discussing residents of flood plains, Kates (1962, p. 140) writes:

> A major limitation to human ability to use improved flood hazard information is a basic reliance on experience. Men on flood plains appear to be very much prisoners of their experience. . . Recently experienced floods appear to set an upward bound to the size of loss with which managers believe they ought to be concerned.

Kates further attributes much of the difficulty in achieving better flood control to the "inability of individuals to conceptualize floods that have never occurred" (p. 92). He observes that in making forecasts of future flood potential, individuals "are strongly conditioned by their immediate past and limit their extrapolation to simplified constructs, seeing the future as a mirror of that past" (p. 88). In this regard, it is interesting to observe how the purchase of earthquake insurance increases sharply after a quake, but decreases steadily thereafter, as the memories become less vivid (Steinbrugge, McClure & Snow, 1969).

Evaluation of low-probability, high-consequence events is likely to be especially sensitive to the effects of availability. For example, ease of imagination almost certainly plays an important role in the public's perception of the risks of injury and death from attack by a grizzly bear in the national parks of North America. In view of the widespread public concern over the dangerousness of these bears, it is indeed surprising that the rate of injury is only 1 per 2 million visitors and the rate of death is even lower (Herrero, 1970). Imaginability of death by the claws of an enraged grizzly is heightened by newspaper stories and movies which only portray attacks, while the multitude of favorable public experiences go unpublished.

The availability hypothesis also implies that any factor which makes a hazard highly memorable or imaginable--such as a recent disaster or a vivid film (e.g., "Jaws")--could considerably increase the perceived risk of that hazard.

Availability bias is illustrated in a recent experiment conducted to study people's perceptions of low-probability, high-consequence events (Slovic, Lichtenstein, Fischhoff, Layman and Combs, 1978). The stimuli were 41 causes of death, including diseases, accidents, homicide, suicide, and natural hazards. The probability that a randomly selected U.S. resident would die from one of these causes in a year ranges from about 1×10^{-8} (botulism) to 8.5×10^{-3} (heart disease). A large sample of college students and members of the local League of Women Voters were shown 106 pairs of these events and were asked to indicate for each pair the more likely cause of death and the ratio of the greater to the lesser frequency.

The results indicated that the frequencies of accidents, homicide, cancer, botulism, and tornadoes, all of which get heavy media coverage, were greatly overestimated. Asthma, emphysema, and diabetes were among the causes of death whose frequencies were most underestimated. These diseases are relatively common in their non-fatal form and deaths are rarely attributed to them by the media. Similarly, the spectacular event, fire, which often takes multiple victims and which gets much media coverage, is perceived as considerably more frequent than the less spectacular, single-victim event, drowning, though both are about equal in terms of actual frequency. A follow-up study showed that these biases in perception could be predicted moderately well from simple indices of amount of newspaper coverage.

In addition to demonstrating availability bias, this study indicates that, contrary to the assumptions of some policy makers, intelligent individuals may not have valid perceptions about the frequency of hazardous events to which they are exposed.

Other Difficulties

What other psychological factors are likely to provide insight into the nuclear power controversy? Several results come to mind.

Desire for certainty. Implementing a new technology is a gamble of sorts, and like other gambles, its attractiveness depends on the probabilities and magnitudes of various gains and losses. Yet scientific experiments (e.g., Lichtenstein and Slovic, 1973) and casual observation show that people have intellectual and emotional difficulties in facing life as a gamble.

For example, risk-benefit conflicts trigger anxiety. One way to counter this anxiety is to deny the uncertainty, to view the world as perfectly safe--or at least safe enough so that one needn't worry about the risk. This happens often with regard to natural hazards such as earthquakes and floods. Thus many of the flood plain residents studied by Kates (1962) flatly denied the possibility that floods would ever recur in their areas. Some thought that new dams in the area made them 100 percent safe. Others attributed previous floods to a freak combination of circumstances unlikely ever to recur. Denial is also observed in insurance decision making where people often treat low probability hazards as if they were completely impossible (Kunreuther, et al., 1977). With nuclear power, the opposite reaction occurs. Risks are seen by some as so great that the decision to stop its development is easily made.

When scientists explicitly point out the gambles involved in societal risk taking, decision makers and the public become upset. Borch (1968) noted the annoyance of businessmen who receive probability distributions from their consultants when what they really want to know is exactly what the outcome of their decision will be. Just prior to hearing a "blue ribbon" panel of scientists report being 95% certain that cyclamates do not cause cancer, Food and Drug Administration Commissioner Alexander M. Schmidt said, "I'm looking for a clean bill of health, not a wishy-washy, iffy answer on cyclamates." (Eugene Register Guard, 1976). Recently, Senator Muskie called for "one-armed" scientists, who do not respond "on the one hand, the evidence is so, but on the other hand. . . ." when asked about the health effects of pollutants (David, 1975). Recently, when people all over the country were demanding to know whether or not the swine flu vaccine was safe, the nature of their demands indicated that they were really trying to determine whether or not it was perfectly safe.

Perseverance of beliefs. The difficulties of facing life as a gamble contribute to the polarization of opinion about nuclear power; some view it as extraordinarily safe, while others view it as a catastrophe. We could take some comfort in the possibility that these beliefs would be responsive to evidence. Unfortunately, even this solace is denied us by research showing the extraordinary perseverance of prior beliefs in the face of contradictory evidence (Ross, 1976). Once formed, initial impressions structure and distort the processes through which subsequent evidence is interpreted. The reliability and validity of new evidence is determined by its consistency with the prior belief. Contradictory evidence tends to be dismissed as unreliable, erroneous, and unrepresentative. Thus, one's opinions tend to be invulnerable to challenges posed by specific bits of information confirming an opposing view or discrediting one's own beliefs. Ross (1976, p. 51) concluded a review of this phenomenon as follows:

> To change impressions, theories, or data processing strategies, therefore, it requires more than exposure to a fair or unbiased sample of new evidence. It is not contended, of course, that new evidence can _never_ produce change--only that new evidence will produce _less_ change than would be demanded by any logical or rational information-processing model. Thus, new evidence that is strongly and consistently contrary to one's impressions or theories can and frequently does produce change--albeit at a slower rate than would result from an unbiased or dispassionate view of the evidence.

Comment

More could be said about maladaptive mental tendencies (e.g., people's misperceptions of causation in probabilistic environments, which leads them to equate good decisions with good outcomes and bad decisions with bad outcomes; biases of hindsight which make people believe, after the fact, that they knew all along what would happen; etc.) but I think, the point is clear. In case I have given the impression that only the layman has problems, I should like to balance the slate. Many of the difficulties and biases have been shown as well in the judgments of experts (Slovic, Fischhoff and Lichtenstein, 1977).

Sinsheimer (1971) argues that the human brain has evolved to cope with certain very real and concrete problems in the immediate, external world and thus lacks the proper framework with which to encompass many conceptual phenomena. People have faced decisions of great consequence like those involving nuclear energy, only within their recent history. Following Sinsheimer's reasoning, it might be argued that we have not had enough opportunity to evolve an intellect capable of dealing _conceptually_ with uncertainty. We are essentially trial-and-error learners, in an age where errors are becoming increasingly costly.

III. Determinants of Acceptable Societal Risks

Policy makers are being required now to "weigh the benefits against the risks" when making decisions about technological enterprises. The ultimate question they must answer is: "Is this product (activity, technology) acceptably safe?" Or, alternatively, "How safe is safe enough?"

Casual attempts to answer these questions provide little insight. To understand why a community lives peacefully astride an earthquake fault or below a great dam, shows little concern over housing a nerve-gas depot within its borders, yet gets up in arms over a proposed nuclear power plant requires an understanding of the determinants of perceived risks and benefits and the criteria for acceptable risk-benefit tradeoffs.

There are, at present, two basic approaches to understanding societal acceptance of risk. One, the "revealed preference" method advocated by Starr (1969) is based on the assumption that society has arrived by trial and error at a reasonably optimal balance between the risks and benefits associated with any activity. Therefore, one may use historical risk and benefit data to reveal patterns of acceptable risk-benefit tradeoffs. Acceptable risk for a new technology is defined as that level of safety associated with ongoing activities having similar benefit to society. The second approach employs questionnaires and psychometric surveys to measure the public's attitudes towards the risks and benefits from various activities (see, e.g., Otway, 1975; Otway, Maderthaner and Guttmann, 1975).

Starr's Approach

Starr illustrated the usefulness of his approach by examining the relationship between risk and benefit across a number of common activities. His measure of risk for these activities was the statistical expectation of fatalities per hour of exposure to the activity under consideration. Benefit was assumed to be equal to the average amount of money spent on an acitivity by an individual participant, or alternatively, equal to the average contribution that activity makes to a participant's annual income.

The results from this analysis are shown in Figure 1. From these data, Starr derived what might be regarded as "laws of acceptable risk;" namely, that (1) the acceptability of risk is crudely proportional to the third power of the benefits, and (2) the public seems willing to accept risks from voluntary activities (e.g., skiing) roughly 1,000 times greater than it would tolerate from involuntary activities (e.g., food

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preservatives) that provide the same level of benefit.

Insert Figure 1 about here

Starr's approach has the advantage of dealing with real behavior rather than attitudes and thus provides an appealing solution to the problem of determining acceptable levels of risk. In fact, a similar approach has already been used to develop a building code regulating earthquake risk in Long Beach, California (Wiggins, 1972). There are, however, a number of serious drawbacks to this method. First, it assumes that past behavior is a valid indicator of present preferences. In Starr's words, "The . . . assumption is that historically revealed social preferences and costs are sufficiently enduring to permit their use for predictive purposes" (Starr, 1969, p. 1232). However, Starr and his colleagues have later acknowledged that "The societal value system fluctuates with time, and the technological capability to follow fast-changing societal goals does not exist." (Starr, Rudman and Whipple, 1976, pp. 635-636). Second, Starr's approach "does not serve to distinguish what is 'best' for society from what is 'traditionally acceptable'" (Starr, 1969, p. 1232). What is traditionally acceptable in the market place may not accurately reflect the public's safety preferences. From a practical standpoint, Otway and Cohen (1975) have shown that the quantitative conclusions one derives from an analysis of the type Starr performed are extremely sensitive to the way in which measures of risk and benefit are computed from the historical economic data. Other critics have noted that risk is not adequately captured by indices that fail to consider quality of death (e.g., the fact that some lethal incidents are dreaded more than others) or the impact of non-fatal incidents (e.g., accidents, genetic defects).

A Psychometric Study of Perceived and Acceptable Risk

Despite its limitations, Starr's approach is worth further analysis. My colleagues, Baruch Fischhoff, Sarah Lichtenstein, and I felt that some of the problematic assumptions could be bypassed by using a direct questionnaire approach to quantifying perceived benefits and acceptable risks from various technologies. We have recently completed a judgmental study of this type in which our subjects, 76 members of the Eugene, Oregon League of Women Voters judged the present risks, acceptable risks, and present benefits from 30 activities and technologies (shown in Table 1). In addition, they also rated each activity or technology on characteristics that have been hypothesized to influence acceptability of risk. These were voluntariness, familiarity, perceived controllability, potential for catastrophe (multiple fatalities), immediacy of consequences, the degree to which the risks are known to the public and to scientists, the extent to which the risks are common as opposed to dread, and the likelihood that a mishap would prove fatal (labeled severity of consequences). Details of the methodology and results can be found in Fischhoff, Slovic, Lichtenstein and Read (1976). A brief summary of the main results follows:

Insert Table 1 about here

1. A methodologically important result is that the task was tractable. That is, it was possible to ask people to make complex judgments about difficult societal problems and receive reliable,

orderly, and interpretable responses.

2. For many activities and technologies, current risk levels were viewed as unacceptably high. These differences between perceived and acceptable risk (see Table 1) suggest that our subjects were not satisfied with the way that market and other regulatory mechanisms have balanced risks and benefits.

3. There appears to be little systematic relationship between the perceived *existing* risks and benefits attributed to the 30 activities and technologies considered here. If anything, the relationship between the two factors is slightly negative, as shown in Figure 2. Our subjects identified a number of current technologies as having a high level of risk but a low level of benefit (e.g., alcoholic beverages, handguns, smoking, motorcycles) as well as a number of activities offering great benefit at relatively low risk (antibiotics, railroads, vaccinations).

Insert Figure 2 about here

4. Level of *acceptable* risk was quite uniform across the items, suggesting that our subjects wanted the risks from different activities to be more equal than they actually are (see Figure 3). Nevertheless, Figure 3 also illustrates a consistent, although not overwhelming, relationship between perceived benefit and acceptable risk. Our subjects also felt that society should tolerate higher risks for voluntary than for involuntary activities (Figure 4). Thus, they appear to believe that Starr's hypothesized relationships should be obtained in a society where risk levels are regulated.

Insert Figures 3 and 4 about here

5. Perceived risk was higher for items whose risks were dread (e.g., nuclear power) and items for which mishaps were certain to be fatal (e.g., airplane crashes), but was not related to any of the other risk characteristics. Acceptable risk was higher for items whose risks were known precisely, immediate, and familiar, and, to a lesser extent, voluntary and controllable. Items whose risks were dread, catastrophic, and certain to be fatal were seen as most in need of reduction in order to be tolerable. Thus all nine of the risk characteristics had some influence on perceived and acceptable risk.

6. The nine characteristics of risk are highly intercorrelated. They can be effectively reduced (by factor analysis) to two risk dimensions as shown in Figure 5. Dimension 1 discriminates between high and low technology activities, with the high end being characterized by new, involuntary, poorly known events, often with delayed consequences. The second dimension, labeled "severity," reflects the certainty of death given that adversity occurs and also the degree to which the risk is "dreaded". Consideration of these two factors made acceptable risk highly predictable. Conceivably policy makers might be able to use such relationships to predict public acceptance of the risk levels associated with proposed technologies.

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Insert Figure 5 about here
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IV. Public Response Toward Nuclear Power and Waste Management

The information in Sections II and III, regarding general intellectual predispositions and attitudes concerning risk, was presented under the assumption that it was relevant to understanding and forecasting public response towards energy systems. The present section examines some basic questions about public acceptance, in light of the material presented above.

Why Is Nuclear Power Presently Unpopular?

The data presented in Table 1 give some clues as to why nuclear power is meeting such great opposition. For one, its benefits appear unappreciated, being lower, for our League of Women Voters sample, than those of home appliances, bicycles, and general aviation. Perhaps this is because nuclear power is seen merely as a supplement to other sources of energy, which themselves are viewed as adequate. Second, its risks are seen as extremely high. Only automobile accidents, which take about 50,000 lives each year, are viewed as comparably risky. Third, the acceptable level of risk is judged to be quite low. Our subjects wanted nuclear power to be far safer than they now perceived it to be.

Why Are Nuclear Power Risks So Frightening?

Nuclear power is frightening because it has the dubious distinction of scoring high on all the characteristics that stimulate risk aversion. Its risks are seen as involuntary, delayed, unknown to those exposed or to science, uncontrollable, unfamiliar, potentially catastrophic, severe (certain to be fatal), and dread. Its spectacular and unique risk profile is shown in Figures 6 and 7 contrasted with non-nuclear electric power and another radiation technology, X-rays (again the data is from the League of Women Voters sample).

Insert Figures 6 and 7 about here

Note that nuclear power differs in all respects from non-nuclear electric power. Nuclear power differs from X-rays on the dimensions of voluntariness, knowledge, familiarity, potential for catastrophic, dread, and certainty of a mishap proving fatal.

Nuclear power is far higher on the characteristic "dread" than any of the 29 other items studied by Fischhoff, et al. This may stem from the association of nuclear power with nuclear weapons (the Hiroshima syndrome) and from fear of radiation's invisible, permanent bodily contamination that manifests itself in terms of genetic damage and cancer (see, e.g., Lifton, 1976; Pahner, 1975).

Nuclear power risks are also highly "available" (e.g., imaginable, memorable) because of their association with nuclear war and because their dread character leads to extensive media coverage which keeps them in the public eye. As Zebroski (1975) noted, "fear sells"--the media dwell on potential catastrophe--not on the successful day to day operations of a power plant.

Will Nuclear Power Ever Be Acceptable to the Public?

I believe that any degree of acceptance of nuclear power could occur, ranging from vehement public opposition, sufficient to topple a government to rather placid acceptance of the sort now bestowed upon X-rays and dams.

Extreme public rejection is likely to originate from nuclear power's high-risk characteristics as discussed above. This rejection is likely to perseverate for several reasons. First, the low probability of nuclear mishaps makes demonstration of nuclear safety difficult from a statistical standpoint. Any mishap will be seen as proof of high risk but proof of high reliability would take a massive amount of evidence (Green and Bourne, 1972). Second, as noted in Section II, new evidence is likely to be distorted to confirm prior beliefs rather than modify them. Thus, as Zebroski (1975) observed, intense effort to reduce nuclear risks may be interpreted to mean the risks are great rather than that the technologists are responsive to the public's concerns. Likewise, minor mishaps are viewed by those with anti-nuclear predispositions as near catastrophes and knowledgable opinions of experts who rebut such claims may be discounted because their close association to the mishap implies that they have some vested interest in minimizing it. Nelkin's (1974) case history of debate during a nuclear siting controversy illustrates the inability of technical arguments to change opinions. She found that information available on both sides of the controversy tended to reinforce the conflicting value positions by highlighting technical areas of ambiguity. Citizen groups used the debate mainly to legitimize their own positions.

Availability bias poses a further barrier to open, objective discussions of nuclear safety. Imagine an engineer explaining the basis for the estimated safety of waste disposal in a salt mine by outlining the fault tree upon which the estimate was based (see Figure 8). Rather than

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Insert Figure 8 about here

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reassuring the audience, such a presentation might have the opposite effect ("I didn't realize there were that many things that could go wrong"). Thus availability effects may make it difficult to engage in objective attempts at discussing low probability hazards without, at the same time, increasing the perceived probability of those hazards. As one frustrated nuclear proponent has lamented, "When laymen discuss what *might* happen, they sometimes don't even bother to include the 'might'" (B. Cohen, 1974, p. 36). Another analyst has elaborated a similar theme in the misinterpretation of "worst case" data:

> It often has made little difference how bizarre or improbable the assumptions in such an analysis were, since one had only to show that some undesirable effect could occur at a probability level greater than zero. Opponents of a proposed operation could destroy it simply by exercising their imaginations to dream up a set of conditions which, although they might admittedly be extremely improbable, could lead to some undesirable result. With such attitudes prevalent, planning a given nuclear operation becomes somewhat perilous since it requires predicting the extent to which the adversaries can employ their imagination. (J. Cohen, 1972, p. 55)

With all this working against it, how could nuclear power gain respectability? Public response to X-rays and nerve gas provides some clues. Widespread acceptance of X-rays show that a radiation technology can be tolerated once its use becomes familiar, its benefits clear, and its practitioners trusted. Of course, X-rays are not perceived as potentially catastrophic, nor do they appear to create the dread presently inherent in nuclear energy (see Figure 7).

The case of nerve gas is even more enlightening. Certainly few human creations could be more dread, more potentially catastrophic, than VX and GB nerve gases. When, in December of 1969, the army decided to transfer these deadly substances from Okinawa to the Umatilla Army Depot in Hermiston, Oregon, citizens of Oregon were outraged--except in Hermiston. Whereas public opinion around the state was greater than 90% opposed, residents of Hermiston were 95% in favor of the transfer, despite the warning that the fuses on the nerve gas bombs deteriorate with age, but the gas does not (*Eugene Register Guard*, December 18, 1969, and January 11, 1970). Hermiston's acceptance of nerve gas illustrates the conditions under which a nuclear reactor or a nuclear waste storage site would be tolerated, perhaps even welcomed by a community (see Figure 9). For one, munitions and toxic chemicals had been stored safely at Hermiston since 1941 (so the record was good and the hazard was familiar). Second, there were clear economic benefits to the community from continued storage of hazardous substances at the depot. Another benefit was the satisfaction of doing something patriotic for the country. Finally, the responsible agency, the U.S. Army, was respected and trusted.

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Insert Figure 9 about here

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The Hermiston example illustrates the long-term path through which nuclear power could gain acceptance. It requires a long-term safety record so outstanding it cannot be denied, the development of respect and trust towards the responsible agency, and, of course, clear appreciation of benefit. The benefit aspect suggests a quicker path to acceptance--one that might be forged by a severe energy shortage resulting in brownouts, rationing, or worse, thus enhancing the perceived benefits from nuclear power and increasing society's tolerance of its risks. A recent example of this is the oil crisis of 1973-74 which broke the resistance to offshore drilling, the Alaska pipeline, and shale oil development, all of which had previously been delayed because of their threat to the environment. Such crisis-induced acceptance may induce anxiety and stress in a population forced to tolerate what it perceives as high risk, because of its addiction to the benefits of electric power.

V. Public Attitudes Towards Nuclear Waste Disposal

To my knowledge, there has been only one in-depth attempt to assess public attitudes and values associated with nuclear waste disposal. This study, done at the Battelle Human Affairs Research Center by Maynard, Nealey, Hébert and Lindell (1976), is important as a first step towards facilitating public input into decisions about waste management. As such, it merits summarizing here in some detail.

Method

The Battelle study was based on questionnaire responses from 465 persons, representing 23 groups of respondents in five regions of the United States. Among those surveyed were members of junior high, high school, and university classes; professional, civic, religious, and service organizations; recreational and environmental activist groups; and scientists and engineers with backgrounds in nuclear engineering and physics.

Questionnaire. The survey questionnaire developed for this study was designed to obtain social value information about the relative importance of four aspects of nuclear waste disposal as well as information concerning some broader issues associated with the subject of nuclear waste disposal. The four nuclear waste disposal aspects or factors which formed the backbone of the questionnaire were as follows:

Short-term Safety: Those risks involved in the storage, transportation, and emplacement of nuclear waste materials. These risks are largely borne by the people who use the electrical power which creates the wastes. These risks would occur during a few years following the creation of the waste.

Long-term Safety: That portion of total risk which would begin after the wastes were finally emplaced or disposed and which would continue for the next 250,000 years. These risks would be due to geological changes and other "Acts of God," and possibly to negligence by man.

Cost: The dollar cost required for a given waste disposal method, as reflected in increased monthly utility bills.

Accident Detection and Recovery: Steps that could be taken to reduce the consequences of an accident if it does occur after final disposal.

The decision to use these four factors as a basis for questionnaire development was preceded by an exhaustive review of numerous other issues which were considered. Other issues considered and ultimately rejected as suitable factors included:

Distance: Remoteness of disposal site from nearest person.

Population Density: Remoteness of disposal site from population centers.

Emplacement Operations: Reliability and safety of procedures used in transporting and disposing of wastes.

Retrievability: Ease with which waste materials could be recovered for emergency procedures or for further processing and the time required to retrieve wastes.

Long-term Stability: Length of time the waste would remain in their disposal location; resistance to acts of nature and acts of man.

Detectability: Extent to which detection of waste leakage would be possible; length of time before leaks could be detected.

Protective Reaction: Extent to which population could be protected if leaks occurred.

Emplacement Costs: Dollar costs involved in transport and disposal of wastes.

R and D Costs: Dollar costs required to develop the disposal technology.

Time Required for R and D: Number of years required to develop and evaluate a given disposal method.

National versus International: Whether wastes would be disposed of within U.S. borders or outside of U.S.

The final choice of the four factors described earlier was dictated by several considerations. One was to have a set of factors which would be useful in describing *any* nuclear waste disposal method currently under consideration as well as any methods which might be proposed in the future. A second consideration was that the factors chosen must be meaningful and salient to participants in the study, and further, that the factors reflect the ethical-philosophical issues associated with nuclear waste disposal.

The questionnaire contained six parts. Three sections were devoted to measuring the relative importance of the four issues cited above using different measurement procedures. Section IV focused on cost/benefit and risk/benefit issues that were relevant to the question, "How safe is safe enough?" This section represented an initial effort to measure public values, attitudes, and perceptions toward risk, defined in terms of fatality rates.

A fifth section of the questionnaire focused on respondents' attitudes toward the broader issue of nuclear energy as an acceptable source of electrical power; attitudes towards nuclear waste disposal, and the relationship between the needs for energy, on the one hand, and the economic health of the nation on the other.

The sixth section of the questionnaire consisted of evaluation and critique by respondents of the methodological approach used in the study. Specific and general reactions to the survey were solicited and respondents were invited to add suggestions and comments of their own.

Film. Prior to administering the questionnaire, a 15-minute film was shown to respondents. This film presented a brief overview of the nuclear waste disposal issue and highlighted the four waste disposal factors emphasized in the questionnaire. Presentation of filmed information was based on the assumption that there was a relatively low level of awareness and knowledge about the topic among the majority of the respondents. One mechanism for obtaining more informed opinions about the topic was to communicate a body of information about the topic to respondents prior to soliciting their input.

An obvious issue concerning the film is whether such information may predetermine or bias the questionnaire data. Efforts were made to minimize this possibility.

Results

Three different measurement techniques were used to assess the relative importance attributed by respondents to the four factors associated with the design of nuclear waste disposal systems: Short-term Safety, Long-term Safety, Cost, and Accident Detection and Recovery. Although there were some subtle differences in the results produced by the three measurement methods, there was generally strong agreement among the three sets of results. For the total respondent sample, Long-term Safety received the highest priority or weight, followed closely by Short-term Safety and Accident Detection and Recovery. Cost received the lowest priority across the three measurement methods. Comparisons among the respondent clusters (shown in Figure 10) indicated that Environmentalists attached the greatest importance to Long-term Safety, while Nuclear Technologists tended to place the greatest emphasis on Short-term Safety considerations.

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Insert Figure 10 about here

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Evaluations of levels of risk and cost. One section of the questionnaire was devoted to measuring the perceived satisfactoriness or acceptability of several levels of risk and cost. The levels which respondents were asked to judge bracketed the range of risks and costs expected to be associated with waste disposal systems. The results indicated that the respondent groups varied considerably in their tolerance for risk, but agreed fairly well with respect to the acceptability of different levels of cost. Nuclear Technologists and Environmentalists differed by as much as two or three orders of magnitude in the judged satisfactoriness of Short- and Long-term levels. These two groups set the risk boundaries within which the average responses for the other respondent groups fell.

These data suggest that the answer to the question, "How safe is safe enough?" varies considerably among individuals for the total sample of the public. Using the aggregated responses for the total sample of respondents, some _tentative_ "best estimates" were derived for what appear to be satisfactory levels of risk and cost for nuclear waste disposal systems.

Attitude data. The attitude data revealed, as we might expect, a clear polarization between the nuclear technologists and the environmentalists with the other groups in between. Table 2 presents responses of the entire sample to selected questions about nuclear wastes. Of interest in Table 2 is the fact that a substantial proportion of respondents felt that cost should be of no concern (Question 3), that loss of even one life from nuclear waste is unacceptable (Question 6), that nuclear wastes should be stored outside their home region (Question 18), and that the generation that receives the benefits should take all the risks (Question 19). Only 7%, however, felt that development of nuclear power should be stopped (Question 27).

Insert Table 2 about here

Respondent evaluation of the survey. Results from the final part of the questionnaire indicated that most respondents felt it was a good idea to consult the public on technological problems such as nuclear waste disposal and generally agreed that the approach used in this study was a reasonable way to obtain public input.

Implications of the Battelle Study

Obviously, the Battelle study is but a first step. Many criticisms could be made of the specific methods that were employed,[1] the four factors that were selected for study and those that were omitted, the adequacy of the instructions and information provided to the participants, etc. Nevertheless, the study does demonstrate that the public wants to provide input into waste management decisions and is willing to grapple with complex questions to do so.

Several results of this study, if confirmed in future research, should be important to planners and decision makers. First, Long-term Safety was a high priority item in the minds of a large number of respondents. Second, respondents judged Cost to be of very minor importance when contrasted with risk considerations. Third, some tentative estimates of acceptable levels of risk were identified. To the extent that different disposal options being considered vary in

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[1] The reader interested in the details of various methods for analyzing public values for social decision making should consult Gardner and Edwards (1975), Hammond and Adelman (1976), and Hammond, Stewart, Brehmer and Steinmann (19[illegible]).

Short- and Long-term Risk, Cost, and Accident Detection and Recovery, some of these findings may be useful in assessing these options from the standpoint of public acceptance.

Some of the more general findings also appear to be highly relevant from a policy perspective. For example, there were pronounced differences among respondent groups in their appraisal of acceptable risk levels, in the priorities they attached to the disposal factors, and in their values and attitudes toward broader issues surrounding the topic of nuclear waste disposal. There is fairly consistent evidence that respondents who were representative of planners and decision makers differed considerably on many key issues from respondents who were more representative of the general public (and particularly from respondents with strong reservations about the efficacy of nuclear power).

This study focused on a set of value dimensions (i.e., Short-term and Long-term Safety, Cost, and Accident Detection and Recovery) which could be used to characterize all nuclear waste disposal options. The respondents were not asked to judge the acceptability of specific disposal options in the questionnaire. Respondents commented about this point and many expressed an interest in the actual disposal methods being considered. A useful area for future research might be directed toward furnishing public groups with information about specific methods, and then measuring their attitudes and opinions about these methods. As the technical assessments and evaluations of disposal methods begin to narrow the range of options, public input regarding their acceptability could serve as vital information for decision makers.

Finally, in case I've begun to sound too optimistic, I should add that, while studies like that done at Battelle can help maximize public acceptance of waste disposal options, they cannot guarantee that even the most attractive option, designed with the public's concerns in mind, will be able to surpass the barriers to acceptance that I described earlier. I expect accepcance of waste management options, like nuclear power in general, to be precarious, subject to great variation with the tide of events.

VI. Summary

A. The study of risk perception and risk acceptability has been much neglected. Nevertheless, there is a small core of knowledge on which speculation can be based.

B. Making decisions about risky activities is difficult, and we may not be well equipped intellectually for the task.

C. Acceptable risk appears to be directly proportional to perceived benefit.

D. Nuclear power scores high on all the qualities that lead to high perceived risk. Its benefits are presently unappreciated.

E. We cannot expect communication from technical experts to allay the public's fears.

F. Either an outstanding safety record or a serious energy shortage could lead to public acceptance of nuclear power. Overall, the acceptability of nuclear energy is likely to be precarious, subject to great fluctuations with the tide of events.

G. There are a variety of techniques for assessing global and specific attitudes towards nuclear waste management. Such information could be valuable for system designers and decision makers.

H. The public wants to provide input into waste management decisions and is willing to grapple with complex questions to do so.

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Table 1 [a]

Judgments of Benefits and Risks from 30 Activities and Technologies

Activity or technology	Perceived Benefit (Geometric Mean)	Perceived Risk (Geometric Mean)	Acceptable Level of Risk
1. Electric power[b]	276	52	50
2. Prescription antibiotics	209	30	23
3. Vaccinations	194	17	20
4. Motor vehicles	187	247	62
5. Railroads	185	37	30
6. Fire fighting	178	93	60
7. Police work	178	111	66
8. Surgery	164	106	56
9. X-rays	156	45	28
10. Large Construction	142	91	56
11. Home appliances	133	25	24
12. Commercial aviation	130	52	40
13. Contraceptives	113	50	25
14. Pesticides	87	105	11
15. Bicycles	82	65	44
16. Swimming	68	53	50
17. General aviation	53	116	56
18. Nuclear power	52	250	9
19. Food preservatives	44	36	14
20. Alchoholic beverage	41	161	36
21. Skiing	38	45	45
22. H.S. & College football	35	37	22
23. Hunting	30	82	34
24. Power mowers	30	29	20
25. Motorcycles	29	176	34
26. Mountain climbing	28	68	69
27. Smoking	20	189	12
28. Spray cans	17	73	10
29. Food coloring	16	31	10
30. Handguns	14	220	13

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[a] Data from Fischhoff, et al., 1978. Respondents were asked to assign a value of 10 to the least risky or least beneficial item, and assign numbers to the other items accordingly. The acceptable level of risk was not judged directly; it was computed from perceived risk using a correction factor which was provided by the respondents.

[b] non-nuclear electric power

Table 2

Responses to Selected Attitude Questions for the Total Sample (from Maynard et al., 1976)

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	Percent Indicating				
3. In dealing with nuclear wastes, cost should be of no concern.	13%	21%	16%	40%	10%
6. The loss of even one life from nuclear waste is unacceptable.	7%	16%	17%	38%	22%
8. The construction of nuclear power plants should be slowed until an absolutely safe waste disposal system has been developed and thoroughly evaluated.	21%	32%	10%	26%	11%
9. Nuclear waste is one of the most serious threats facing the world.	9%	22%	20%	33%	16%
11. Future generations must be totally safe from our nuclear waste.	23%	37%	18%	17%	5%
13. The benefits of nuclear power more than outweigh the hazards in nuclear waste storage and disposal.	12%	32%	20%	24%	12%
18. I would not want to have nuclear wastes disposed of in my region of the country.	21%	35%	10%	26%	8%
19. The generation that uses nuclear power should take all the risks for waste disposal.	11%	26%	17%	33%	13%
22. Participating in this study makes me realize just how frightening nuclear waste is.	7%	26%	24%	29%	14%
27. We should immediately stop developing nuclear technology as an energy source.	2%	5%	11%	39%	43%
28. The main concern of nuclear waste planners should be a safe system for the short term.	5%	21%	15%	46%	13%

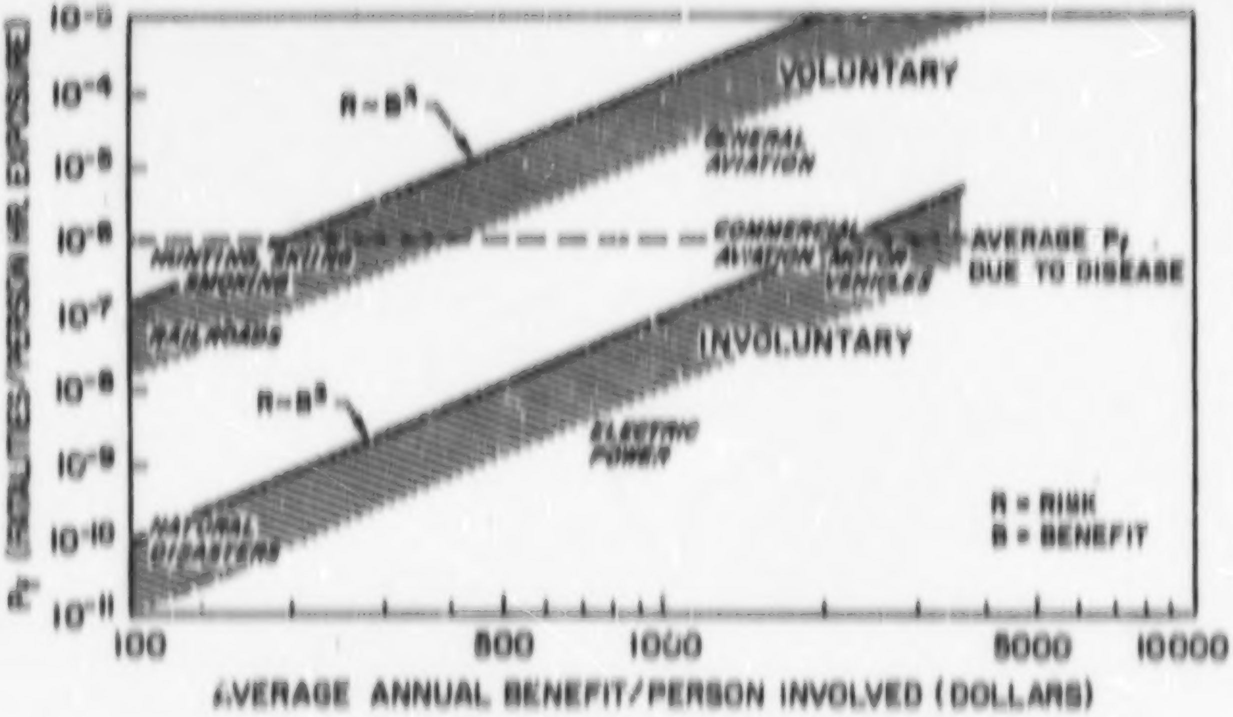

Figure 1

Risk versus Benefit, Voluntary and Involuntary Exposure
(From Starr, 1969)

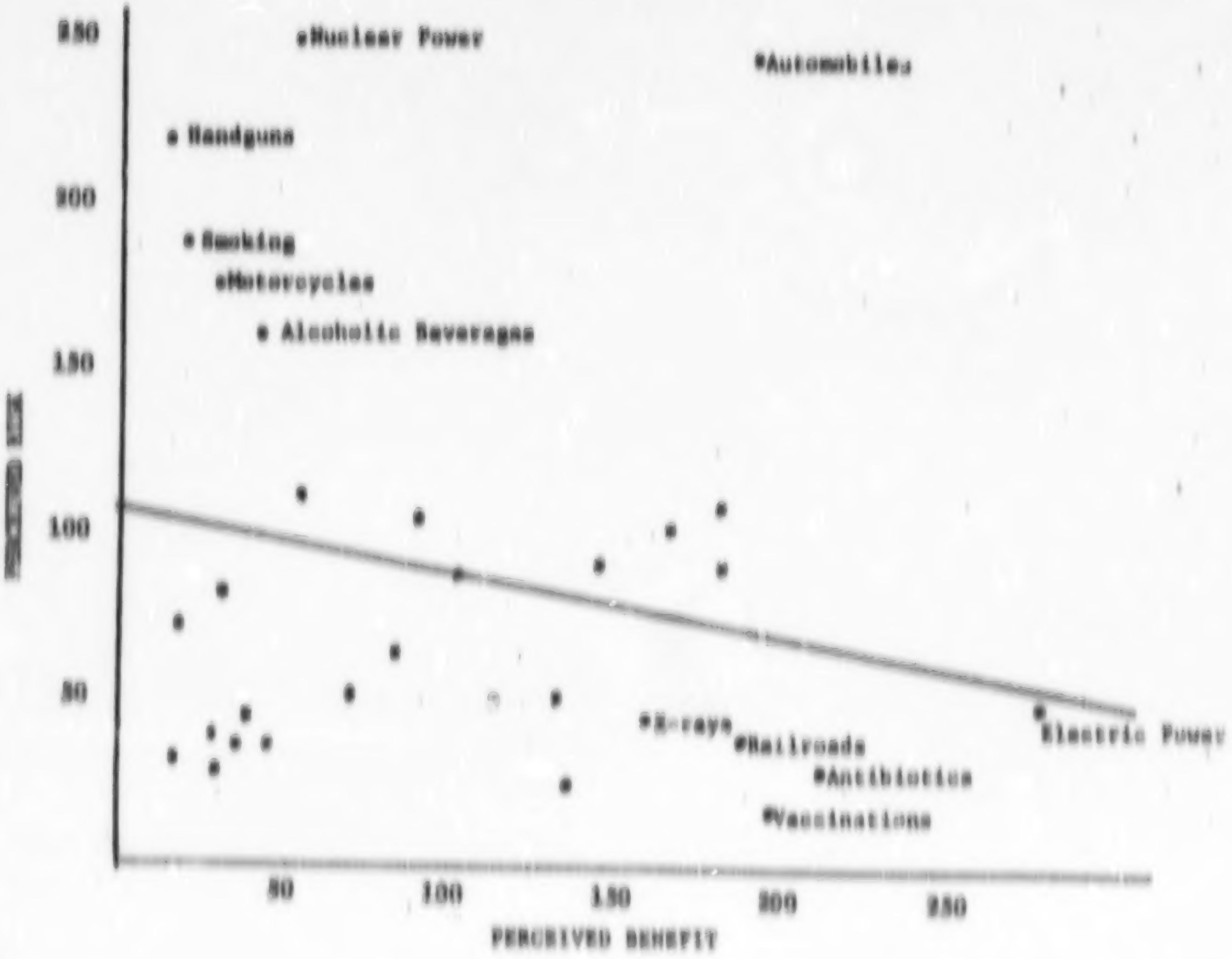

Figure 2
Relationship Between Perceived Risk and Perceived Benefit
(From Fischhoff et al. League of Women Voters Study)

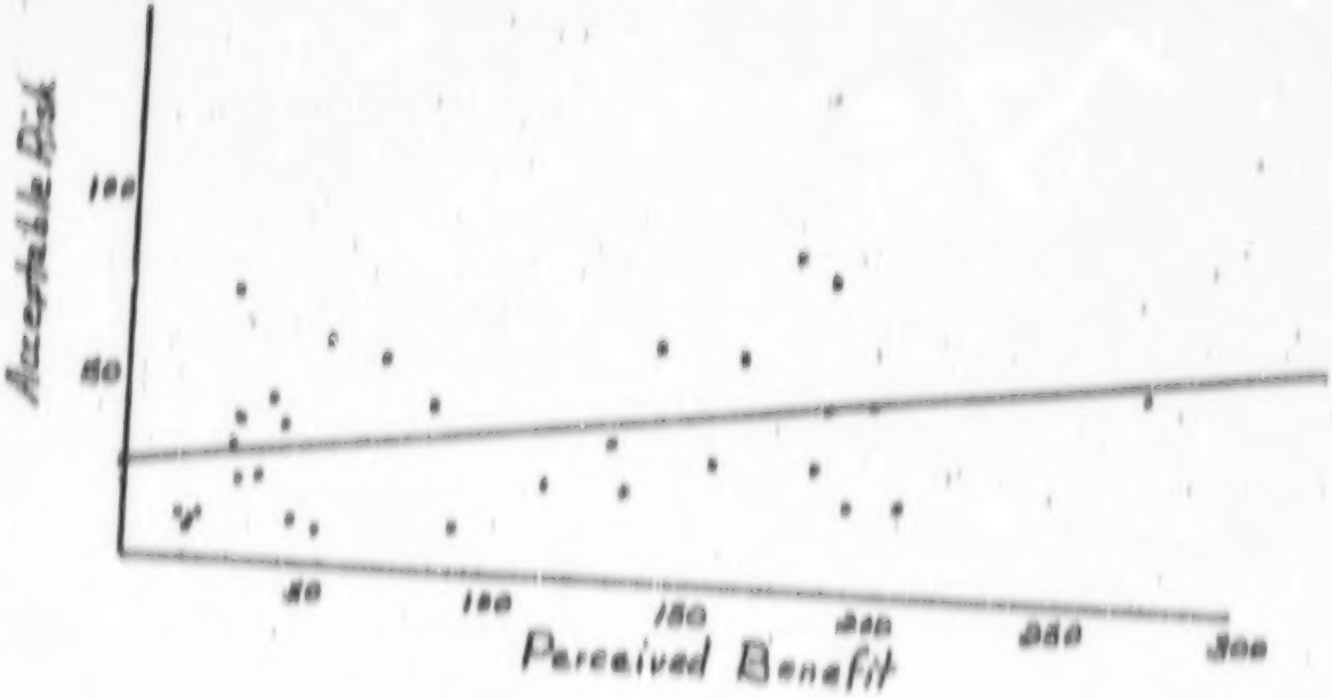

Figure 3

Relationship Between Perceived Benefit and Acceptable Risk

(from Fischhoff et al.)

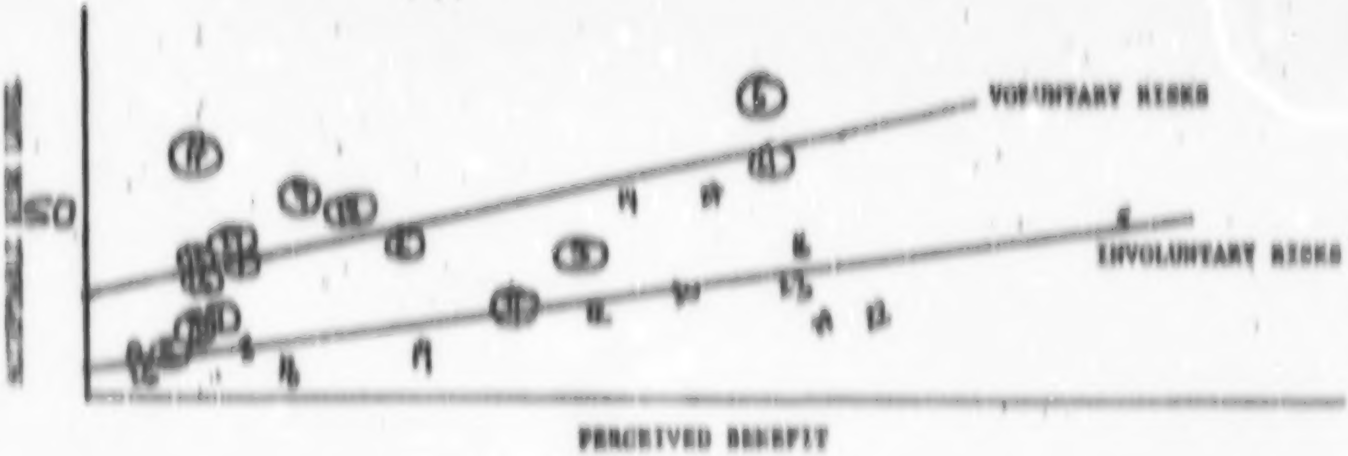

Figure 4
Relationship Between Perceived Benefit and Acceptable Risk
for Voluntary (circled) and Involuntary Items
(from Fischhoff et al.)

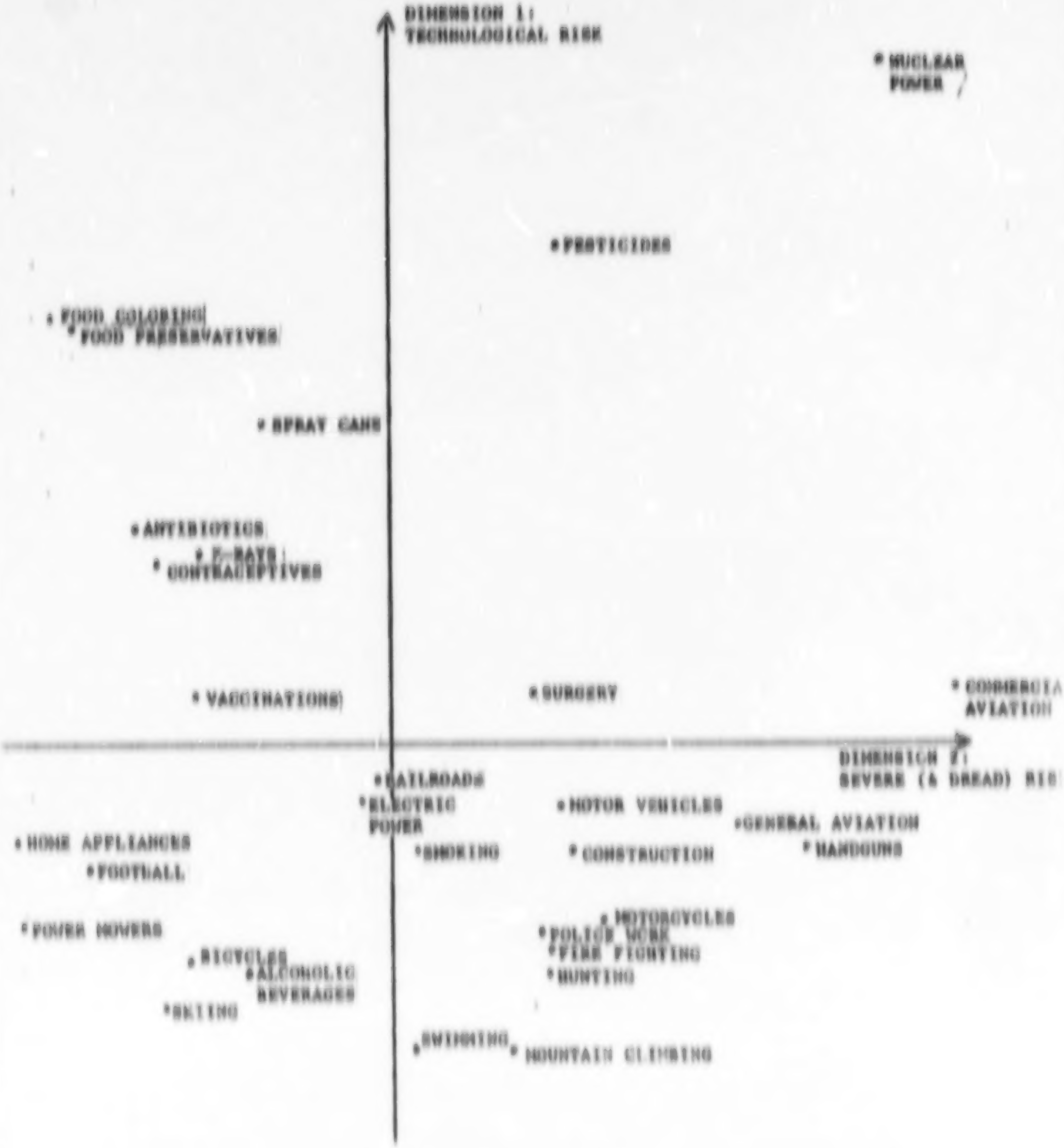

FIGURE 5. LOCATION OF RISK ITEMS WITHIN THE TWO DIMENSIONAL SPACE
(from Fischhoff et al.)

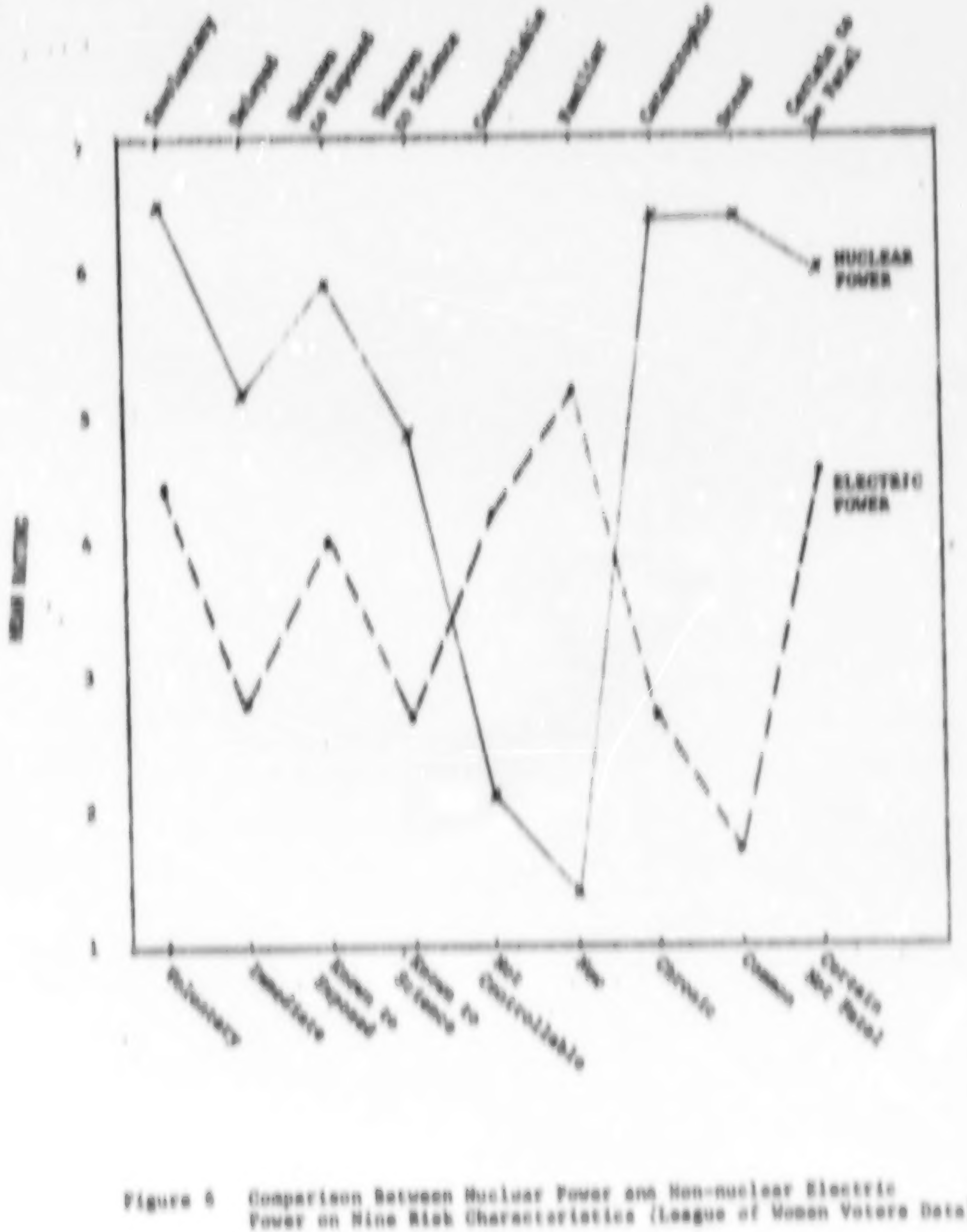

Figure 6 Comparison Between Nuclear Power and Non-nuclear Electric Power on Nine Risk Characteristics (League of Women Voters Data)

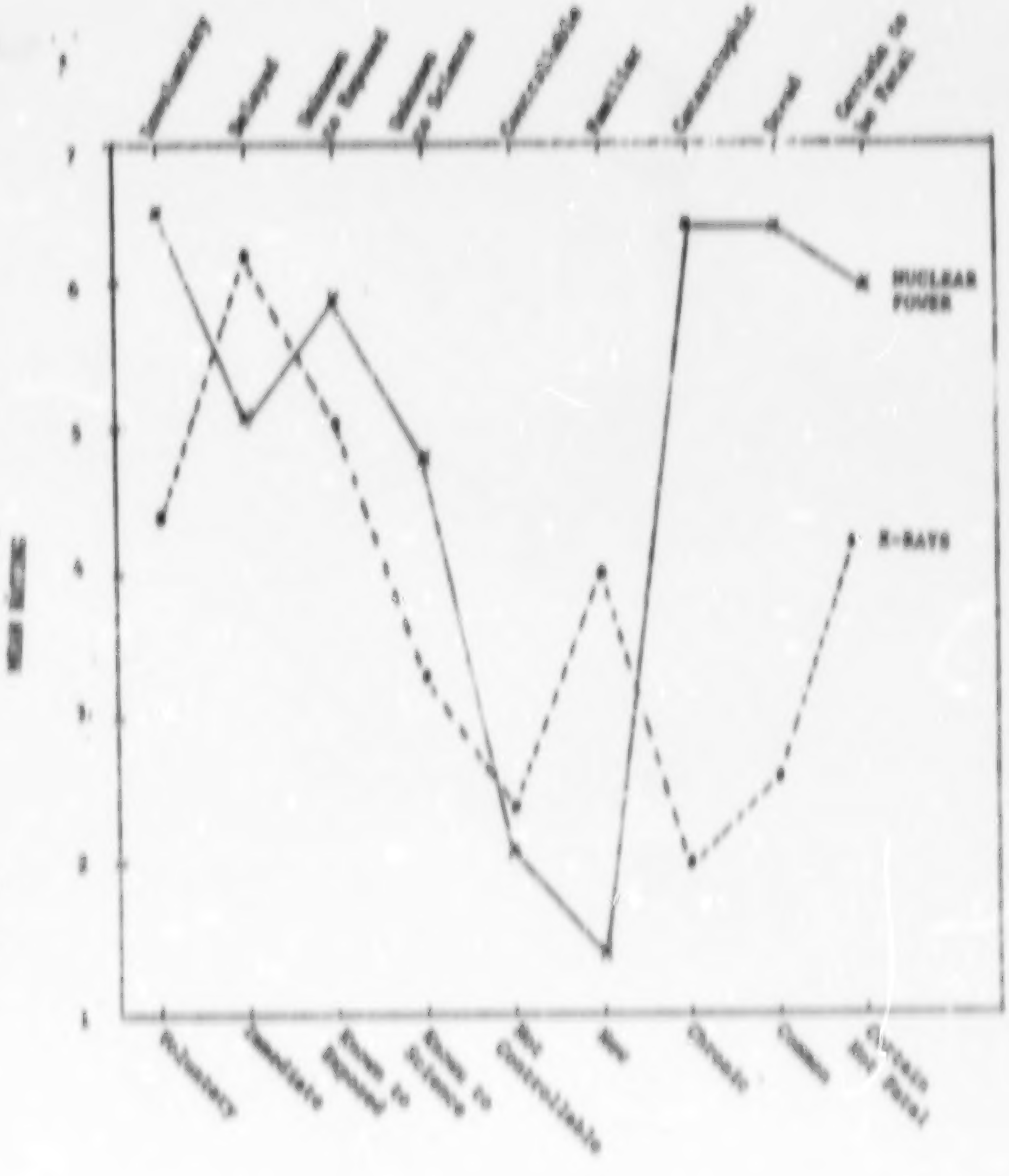

Figure 7 Comparison Between Nuclear Power and X-Rays on Nine Risk Characteristics (League of Women Voters Data)

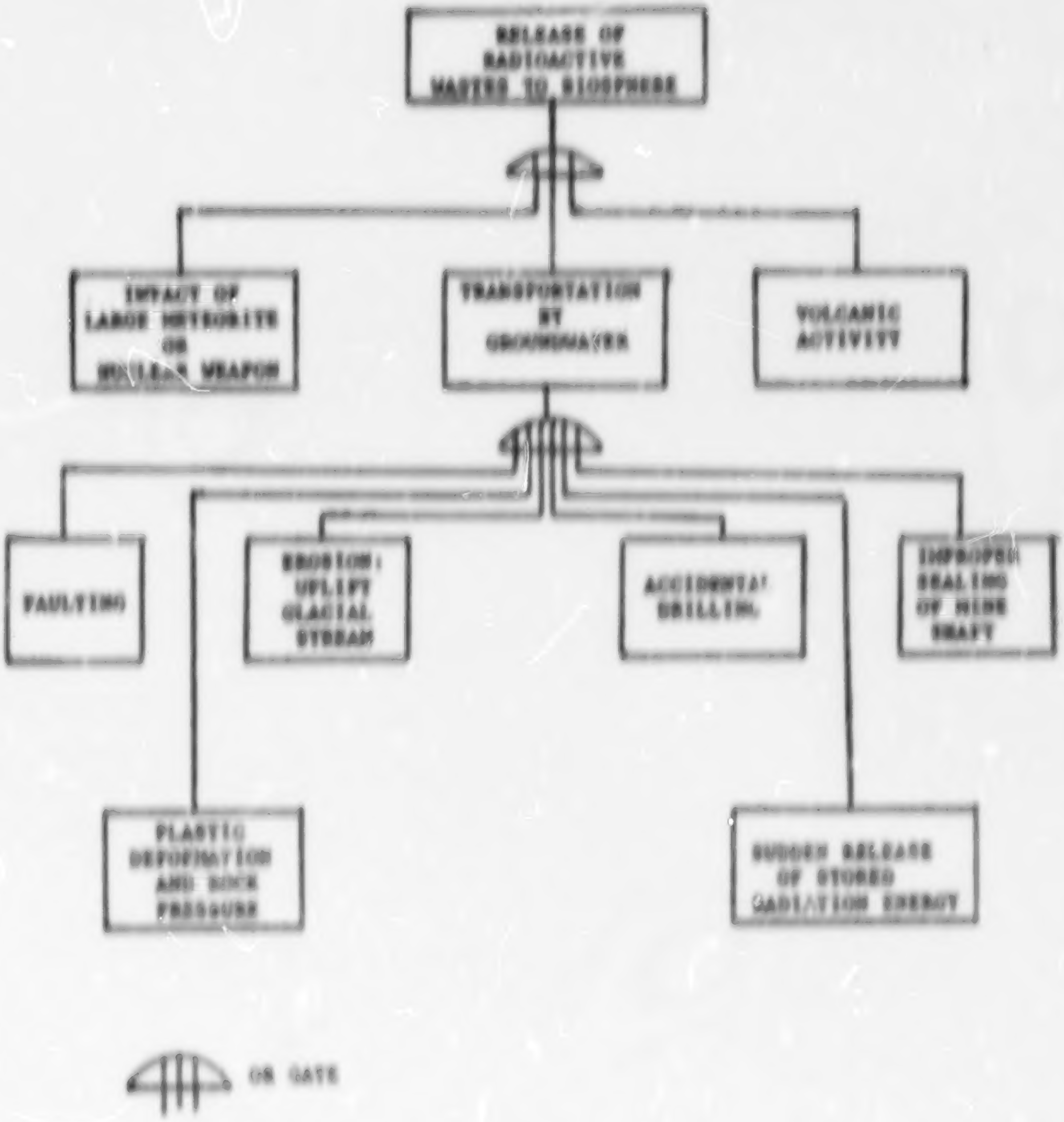
RELEASE OF RADIOACTIVE WASTES TO BIOSPHERE
IMPACT OF LARGE METEORITE OR NUCLEAR WEAPON
TRANSPORTATION BY GROUNDWATER
VOLCANIC ACTIVITY
FAULTING
EROSION: UPLIFT GLACIAL STREAM
ACCIDENTAL DRILLING
IMPROPER SEALING OF MINE SHAFT
PLASTIC DEFORMATION AND ROCK PRESSURE
SUDDEN RELEASE OF STORED RADIATION ENERGY
OR GATE

Figure 8

Fault Tree of Salt Mine Used for Storage of Radioactive Wastes (after closure of the mine). From McGrath (1974).

Page 86, EUGENE REGISTER-GUARD, Sunday, January 11, 1970

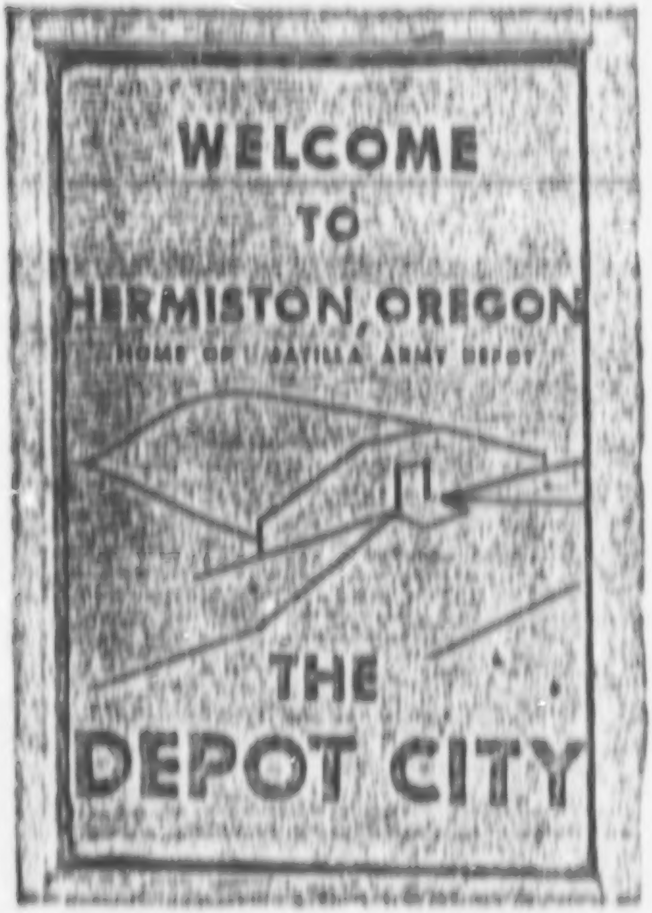
WELCOME
TO
HERMISTON, OREGON
HOME OF UMATILLA ARMY DEPOT
THE
DEPOT CITY

Figure 9: A Sign Welcoming Visitors to Hermiston, Oregon

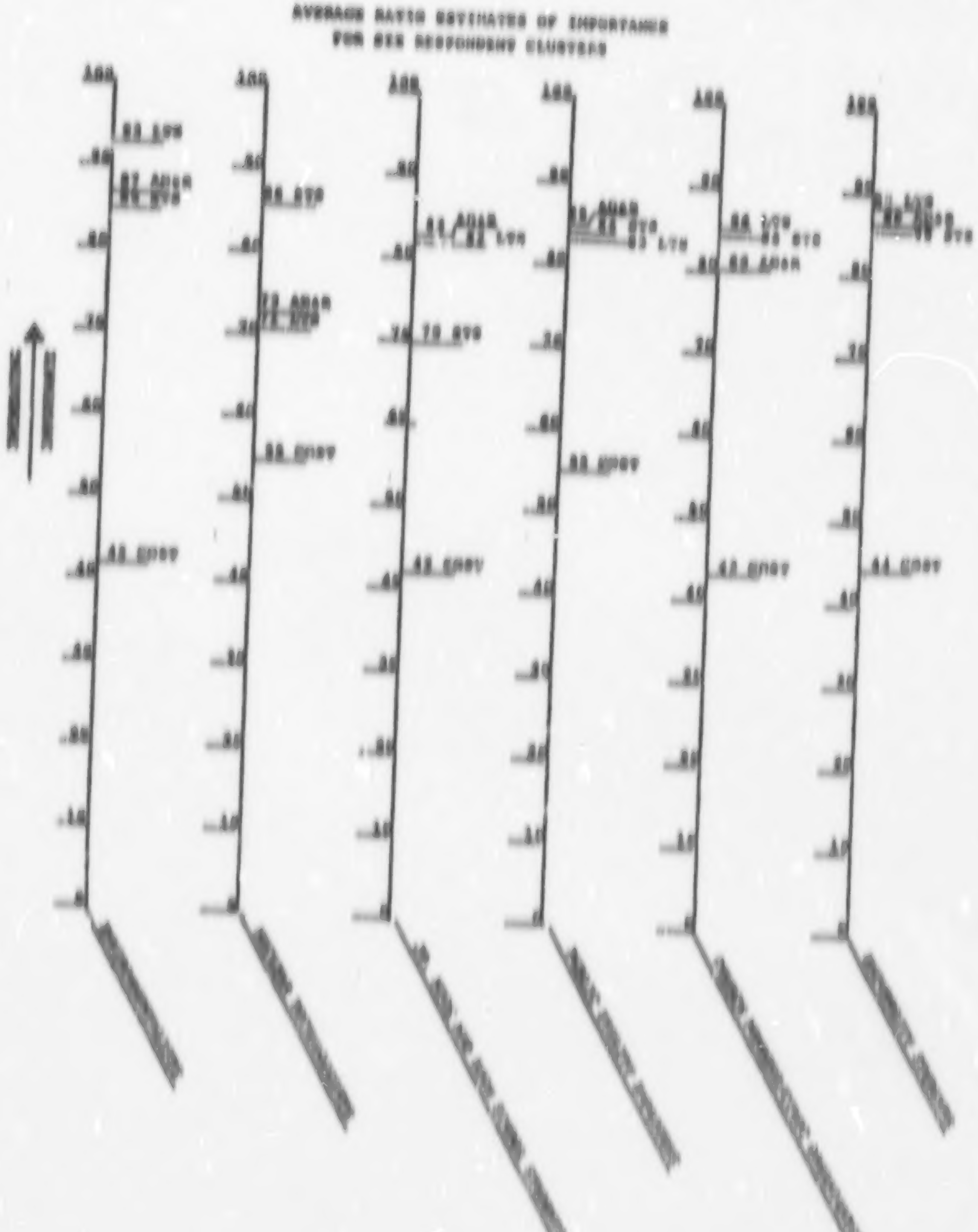

Figure 10
Average Ratio Estimates of Importance
for Six Respondent Clusters
(From [illegible] et al., [illegible])

Criteria for Choosing Among Nuclear Waste Management Alternatives

Mark Sharefkin *

Introduction

This paper is an effort at a logical reconstruction of some arguments surrounding the generation and management of high-level nuclear wastes. Though those arguments are in part technical, in the sense of turning upon assertions about geology, hydrology, or radiobiology, the premise of the paper is that the heart of the matter is nontechnical: that conclusions drawn from the same facts, and the often-implicit value standards used in moving from facts to policy conclusions and recommendations, are what is at issue.

For this reason my own views of the waste disposal problem are of less importance that the attempted reconstruction. The first substantive section of the paper begins that work by trying to isolate, for analytical purposes, some of the distinct kinds of nuclear waste-associated hazards, and some of the criteria invoked in discussions of those hazards. The emphasis in that section is upon sorting things out, and upon seeing how special or general some of the features of the nuclear waste problem are.

A subsequent section of the paper applies these sharpened criteria to what I will call adequately characterized versions of "the" waste disposal problem, in an effort to examine their implications. The versions, or cases, of that section are constructed by compounding the separate special features defined in the earlier section of the paper. I proceed from simpler to progressively more complicated versions of "the" problem. In each of these cases I begin, with examples, the task of the last section. The problem is to look at what we do, as a society, in those nonnuclear cases conceptually most simi-

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* Senior Research Associate, Resources for the Future, Washington, D. C.

lar to the pricipal nuclear cases.

In a final section I suggest some crude quantitative measures relevent to these comparisons. I believe that even these crude measures are helpful in bringing some realism to discussions of nuclear waste management policy.

Criteria for Choice

Choice among alternatives, if it is not to be arbitrary, must be choice subject to criteria. The questions which we are grappling -- whether to generate electricity in ways that generate high level nuclear wastes, and how to treat those wastes if we do choose to generate them -- involve choices, and thus criteria, at several levels, and we can save ourselves much trouble later if we try to be clear about those levels of choice at the outset.

Perhaps easiest to distinguish are choices among technical alternatives for waste management and choices among institutional alternatives for waste management. In principle we can at any given time list the full range of available technical waste disposal alternatives. Criteria for choice among technical alternatives are criteria for ranking or otherwise ordering these technical alternatives. For example, the one of the simplest such criteria is the (internal) economic cost, stated either as a per annum per kg cost or as a discounted present value over some future overall nuclear program cost, of each waste disposal alternative. This criterion has the virtue of unambiguously ranking all lternatives, since it reduces them to a single number. It also has the serious defect of ignoring the nonmarket costs and benefits of the various alternatives.

Criteria for choice among institutional alternatives must rest primarily upon criteria for choice among technical alternatives and their consequences. But institutional choices also rest upon considerations of the value of institutional arrangements per se.

These criteria are difficult to formulate precisely and even more difficult to use sensibly. But many important problems, nuclear waste management prominent among them, involve an essential tension between technical (or performance) criteria and institutional criteria. For illustrative examples I turn to the Anglo-American institution of trial by jury in criminal cases. Pretend for the moment that we have selected this over alternative possible arrangements, such as trial by fire or administrative law trial. Pretend further that in choosing among these alternative arrangements we were agreed that conviction of the guilty and exoneration of the innocent was the appropriate standard.

Then in choosing among alternative trial arrangements we can ask of each: how frequently will it lead to the conviction of the innocent, and how frequently to the exoneration of the guilty? Were we clever enough to model each process, we could make estimates of the frequency of each type of error. Were we willing to go one step further, a value judgment weighting these two errors, we would have a ranking of trial arrangements, and we could pick the best of them.

Of course the real difficulties arise in our imperfect understanding of, and in the unpredictable and changing nature of, the relationship between institutional arrangement and institutional performance. More representative trial juries should be fairer, and their performance better by our guiding standard. But there are times when local conditions preclude formation of a jury at once representative and unprejudiced, and venue can be changed. Similar problems arise in the nuclear waste management case, for there the range of institutional alternatives is particularly broad, and the relationship between those alternatives and performance standards no less elusive.

So much for the distinction between choices among technical, as opposed to institutional, alternatives. For criteria for both kinds of choice there is a further set of relevant distinctions: between criteria for individual choice, criteria for social, or public, choices made by several or many individuals, and criteria for choices only partly under the control of the choice-making individual or group. Though few real-world problems fall cleanly into one or another category, treating some real-world problems as if they did can be instructive. Thus treating a problem as an individual choice problem can be instructive in indicating that either unfocused choices are being made or that "hidden" values are being expressed; those values then become explicit. Consider the case of a mountain climber who goes to considerable cost and trouble to engage in an activity far more hazardous than driving an automobile. While this is irrational for an individual whose subjective valuations of all hazards are similar, it can be entirely rational for an individual to whom the hazards of mountaineering are different in kind from the hazards of the highway.

Similarly, treating a problem as if it were a problem of social, or public, choice among alternatives is helpful in clarifying one salient feature of the nuclear waste management controversy. Different individuals can and do value the same hazard very differently. Consequently, when a specific technical alternative subjects many individuals to the same risk, it may be difficult to reach a consensus of valuation of that risk. But this is true of many other kinds of goods and services with similar public good aspects, including national defense and education. Recognition of this set of similarities is helpful, for somehow, despite these difficulties, we manage to reach collective decisions on defense and education. Finally there is the problem of choosing among alternatives when there are other parties to the decisions: what changes in decision criteria are required? The United States alone cannot exercise decisive leverage over foreign nuclear fuel cycle developments, including waste management policies, and criteria for choice among alternative American waste management institutions must be shaped accordingly.

We turn from this somewhat abstract typology of criteria, and to the subfor nuclear waste management based upon explicit worst-case assumptions.

Explicit Worst-Case Requirement: the worst case invoked should be explicitly defined in both consequence and (subjective) probability.

This requirement does not rule out dominance of the decision by the worst case cited: but it does require that imprecise terms (catastrophe, unparalleled) be rendered understandable, and comparable, that probabilities be "believable," and minimally consistent with known transport properties. Given such an explicit estimate, we can specify how risk-averse we as a society must be if that worst case is to dominate our waste management decision, and, we can at least ask whether plausible levels of individual and/or social risk aversion lead to an unambiguous decision. Some of these latter terms have not yet been defined: that is the burden of the next subsection.

(CR) Collective Risk: some in discussions of nuclear waste management cite the large numbers of individuals at risk in the worst cases as a special, and a distinguishing, feature of the problem. It may be helpful here to clarify the distinction between collective and individual risk, and to indicate how commonplace risks of both polar cases are.

Individual risks are risks borne by individuals: their incidence is unpredictable at the individual level but is highly predictable, in an actuarial sense, for a large number of individuals. Very roughly, these are the familiar insurable risks of death, medical expense, fire and theft: they are insurable because they are individual risks. Thus an insurance company can be essentially certain that the probability of all the homes it insures against fire burning to the ground in one day is negligible, and thus can sell insurance at a price equal to the sum of expected individual loss and administrative charges. And because most people prefer slightly smaller, certain income over a slightly larger expected, but more uncertain income -- because, in general, most individuals are "risk averse" --

stance of the paper, the articulation of criteria and the analysis of their virtues, defects, and implications.

"Special Features" of the Nuclear Waste Management Problem

Here we want to look at some conceptual problems in the evaluation of alternative nuclear waste management technologies. Each of these problems is at times invoked as a distinguishing feature of the waste disposal problem. But I beleive that each is in fact a familiar kind of problem, dealt with, in practice and in theory, elsewhere. Each is susceptible of treatment in a relatively straightforward way, so that there is a natural congruence with decision criteria. I reiterate that I have little to add here to an abundant literature on the technical aspects of the nuclear waste management problem, and that, in my zeal to clarify and reduce, some technical features of that problem have necessarily been given short shrift and caricatured.

Many popular discussions of nuclear waste management mix some, or all, of four identifiable features of the problem, or rather four ways of perceiving the problem. For reference I have labelled these with letters. Ordered from most tractable (or perhaps most easily dispensed with) to least tractable, they are Uncertainty (U), Collective Risk (CR), Irreversibility (IR), and Intergenerational Transfers (IGT). Here we treat these one at a time, *seriatim*, and only later do we mix them into more formidable and realistic compound cases, to see what can be done with realistic problems.

(U) Uncertainty: here this term is intended in the specialised sense of uncertainty rather than risk. A situation is risky when all possible outcomes and their corresponding probabilities are known ex ante (though of course the particular, ex post outcome is not). A situation is uncertain when either those outcomes, or their probabilities, are known only incompletely. The throwing of a perfect die, or participation in a fair lottery, puts the participant at risk; the funding of

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pure research in, say, differential topology, subjects the grantor to uncertainty, for the results of such research, and thus the fruits of that expenditure, are almost impossible to predict, let alone probabilize.

It is frequently suggested that probabilistic-based methods are irrelevant to descriptive and/or normative analyses of nuclear fuel cycle linkages, because the situations are situations of uncertainty rather than of risk. Thus it has been suggested that the Rasmussen report is vitiated by the impossibility of anticipating all outcomes and all accident sequences leading up to those outcomes. Similarly, regarding the waste management problem, it has been suggested that, because all technical outcomes cannot be foreseen (tank leakages of intermediate high level waste storage, for example, or the existence of adjacent but unknown borings in a prospective salt depository, for another), applications of probabilistically-based methodologies are similarly ruled out here.

This view, I believe, arises from an essential misunderstanding of the theory of choice under uncertainty. That theory is based upon nothing more complicated than the implications of some very simply consistency requirements for choices, for example the requirement that choices be transitive (if lottery A is preferred to lottery B, and lottery B to lottery C, then lottery A is preferred to lottery C). The range of theory can be extended to include, as an alternative, the possible choice of not deciding now, but rather of gathering more information on outcomes and associated risk probabilities, and deciding later. This kind of extension will occupy us later, but I believe that the heart of the objections cited above lies elsewhere. Closer, I believe, is the belief that a realistic worst-case outcome is being excluded, or assigned an unrealistically low probability. The worst-case probabilities, and for that matter all the probabilities in the problem, are necessarily somewhat subjective, and so we can and must ask that individual objections to probabilistic assessments of alternative technical strategies for there will be takers.

Because there are insurance markets in which individual risks are spread, individuals are forced to reveal their risk attitudes in those markets, and that revealed information is helpful in valuing other kinds of risks -- collective risks -- for which there are no markets. Parenthetically, information about individual attitudes toward risk is revealed not only in insurance markets, but also to some extent in individual occupational choices. Because greater wage compensation is required to offset the greater riskiness of some occupations --

steeplejacking over bricklaying, for example -- it is possible, with the help of some econometrics, to extract a numerical estimate of how individuals trade income against risk at the margin.

Collective risks, our real interest in this section, are distinguished from individual risks in that they are risks borne by all members of some group of individuals at risk. The risk of death in an airplane crash is borne by all passengers on a given flight, the risk of an electric power blackout by all electricity customers in the relevant service area, and the risk of unemployment in recession by much of a nation's working population. Comparison of the extreme cases of pure individual and pure collective risk heightens an essential difference between the two. Collective risks are noninsurable; insurance markets in which these risks are valued and allocated generally will not exist, and some other mechanism is necessary if we want to do better, or do more than to just take our chances with these risks. The reason insurance markets do not form is fairly clear: there is no way to spread the risk. Thus unemployment insurance markets do not exist because, in the event of a slump, many individuals will have to be compensated simultaneously.

Most real-world risks fall somewhere inbetween the extreme of individual and collective risk cases; and for many real-world collective risks, we can try, by expending real resources in risk-reducing activities, to buy our way, at least in part, out of the gamble. An airline crash may be fatal to all aboard, but those aboard are nevertheless a small fraction of the population and even a small fraction of all travelers. Though insurance markets cannot function here, there is such a thing as crash insurance sold at rates that are actuarially quite unfair, and sold only to those aboard the insured flight. And there are innumerable measures -- air traffic control, additional instrumentation, changes in aircraft performance standards -- which can reduce air travel hazards.

Because individuals in general value hazard reduction, there is, in principle, some best compromise between risk-reduction costs and residual hazard, with individuals indifferent between that hazard and further risk-reduction expenditure. In principle, we can expend about the right amount of resources in order to reduce collective risks to an optimal level; at which valuations of further, marginal hazard reduction by those individuals at risk equals the cost of marginal reduction in accident probability. And, in principle, we can use individual hazard evaluations, revealed in individual-risk insurance markets and in occupational choices, for guidance on the benefit side, and safety engineering cost estimates for guidance on the cost side.

As always some caveats stand between these generalities and empirical applications. The first is that collective risk reducing activities are typically undertaken, and financed, by a mix of the contributions of the individuals participating in the service at risk and by the government. In the airline safety case, for example, air traffic control is financed by airport fees levied on air travelers, but some FAA activities are financed out of general revenues. Thus not only the hazard valuations of the passengers at risk, but also the hazard valuations of the Congress and the FAA, are revealed in the outcome. Society as a whole seems willing, here and elsewhere, to pay something extra for collective risk reduction. (Put still another way, society is willing to pay more to reduce the expected number of air crash victims in a given year by 300 than it is willing to pay to reduce the number of auto accident victims by 300.) The summing of individual valuations of hazards reduction therefore typically understates the social valuation of the loss, because individual valuations of individual hazard do not incorporate this social valuation effect.

A second caveat cuts in the other direction, suggesting the conclusion that summed individual valuations may not be so bad a measure of proper social evaluations after all. This is the problem of preference revelation, arising from the nonexistence of insurance markets for the collective risk and from the imperfection of the devices for determining the optimal amount of hazard-reduction expenditure. For when hazard reduction costs are not expenditures borne entirely by those participating in the activity in question -- air travelers in our illustrative example -- each individual has an incentive to give strategic, rather than sincere, answers to questions designated to determine his willingness to pay for hazard reduction. (By strategic we mean answers conditioned on the respondent's expectation of others' answers and upon the chosen arrangement for aggregating the individual answers into a level of hazard reduction decision). If, for example, the amount of hazard reduction to be purchased will be the average of the individual answers, and if a particular individual believes that most other individuals want less hazard reduction than he does, that particular individual has an incentive to submit a strategic overestimate of his actual desired level of hazard reduction, in order to pull up the average.

For this reason we are reluctant to dismiss out of hand, and in fact we will depend in part upon, revealed individual risk valuations in those market-like environments, described above, in which sincere choices are compelled: we believe they are useful benchmarks.

(IB) Irreversibility: perhaps the salient feature of nuclear waste management is the unprecedented time scale of the management problem. Naive use of waste product half-lives as measures of the scale of "the" management problem leads one almost immediately to the conclusion that the problem is forbidding. Thus one can appeal to the 17 million year half life of I^{129}, or the 24,400 year half life of Pu^{239}, or even the 500 year decay period of fission products from which the transuranics have been removed. But the I^{129} case involves a half life so long, and a specific activity so low, that there is almost no problem; stable isotopes are in a sense only very long-lived, and therefore very long half-lived, isotopes. Obviously, the relevant problem measure must depend upon both parameters, specific activity and half-life. But it is not at all clear, from the waste management literature, what measure has been chosen, and why.

In trying to focus upon what the problem is, I have found it helpful to state several rules of thumb, or rules for guidance, and to consider their properties in turn. I have, for present expositional purposes, somewhat artificially separated the very much interrelated problems of Irreversibility and Intergenerational Transfers. Much of the concern with irreversibility in the context of nuclear waste management in fact centers upon worst-case transfers of an actinide contaminated biosphere to all future generations. Later, we will have to piece together these problems. Let us begin with the following candidate criterion for irreversible nuclear-related decisions. Even when, or perhaps especially when, this criterion is left implicit, many find it compelling.

Long-lived Nuclide Exclusion Criterion: No activity shall be undertaken in which radionuclide residuals are generated which will outlast the beneficiaries of the residuals-generating activity.

As a prior value judgment, this criterion is logically unassailable. It is rather the implications of this criterion that I find disturbing, for several reasons. The first is its facile inflation of a microscopic physical irreversibility into a macroscopic, and indeed a global, ecological irreversibility. The second is its peculiar insistence upon single energy source instrument for attainment of a more general objective. The third, tied closely to the first two, is its deficiency as a standard for guiding information-gathering strategies applicable to all energy sources with potential long-term consequences. In what follows, these three deficiencies of the Long-lived Nuclide Exclusion Criterion are taken up more or less *seriatim*; other, improved criteria are stated as they arise.

A clear statement of the relevant notion of irreversibility is itself a treacherous enterprise. At what level of cumulative waste generation is the threshold of irreversibility crossed? Irreversibility presumes foreclosure of some possibility, of some "option"; and future options can be foreclosed when the re-creation of a preexisting state has been rendered technically infeasible. (This is what the very different examples of irrevesibility -- the destruction of a unique and irreplaceable Da Vinci masterpiece, or the irreversible commitment of trace contaminants to the biosphere -- have in common.) But in practice there are few sharp thresholds other than those imposed by willful classification, and reversibility is largely a question of cost. In particular, I believe there are essential differences between the nuclear waste management problem and the problems associated with the dispersion of trace toxics, such as pesticides, in the biosphere. In the latter case environmental dispersion is a necessary step in the use of the agent; what is uncertain are the residence lifetimes, and pathways, of the agent in the biosphere. But I would argue that, in the nuclear waste case, technical uncertainties surround only the containment, and not the transport, linkages.

A second set of undesirable features of the Long-lived Nuclide Criterion is its focus on only one set of energy-related hazards. There is of course an inexhaustible and clean way of generating electricity. But I believe that the present costs of solar electric power are so much higher than the costs of competing fossil and nuclear alternatives that the real range of choice spans only those competing alternatives. In the ensuing discussion we therefore assume the availability of only those competing fossil and nuclear alternatives, somewhat idealizing the properties of each.

For present purposes our concern is with the "selfinflicted irreversibilities" associated with each energy source. A rational mix of energy sources would presumably be based, in part, upon a comparison of the irreversibilities, as well as upon the internal costs, of energy from each source.

The precise specification of shadow prices required for weighting the irreversibilities is delicate, and my comments here are very rough: what precision I have been able to muster is postponed to the next section of the paper. The simplest kind of irreversibility, common to both energy sources, is the depletion of a nonrenewable resource. This particular irreversibility is not central to our concerns, and I beg off with the rather cavalier assumption that the scarcity price component of market price covers this component of irreversibility, all within the internal cost of delivered energy. The more serious and more interesting irreversibilities associated with the two sources are, for nuclear, the possible commitment of an actinide burden to the biosphere, and for coal and other fossil fuels, the long-term buildup of atmospheric CO_2. In each case the sequences to seriously disruptive outcomes are still hypothetical: the nuclear case worst sequence to biosphere actinide contamination, and the fossil case sequence to higher atmospheric burdens, and from there to irreversible climatic changes.

But the two hypothetical sequences are, we believe, significantly differentiated by the place in the sequence in which uncertainties lie, and the possibility of gathering information about each sequence prior to irreversible commitment. In the fossil case there is presently no question that CO_2 is being committed to the global atmosphere. But because there is only one global atmosphere, there is no serious possibility of experimenting with that atmosphere short of running the full risks of the worst-case fossil sequence. The uncertainties in the hypothetical nuclear sequence are, by contrast, in the environmental transport sequence, with respect to which it is possible to do localized experiments.

For the crucial determinants of the transport and dispersion of actinides in the biosphere do not in any way depend upon the radioisotopic, but rather upon the physical and chemical properties of the actinides. Their radioactivity in fact makes information gathering easier. The sad fact that we have, through weapons testing, already gathered considerable information on the transport of these nuclides in the biosphere is still futher weight on the side of my conclusion: that irreversibility-type arguments, especially ones based upon the possibility of gathering information prior to making a decision to run the risk of an irreversible commitment, are far from favoring fossil energy sources over nuclear energy sources.

(III) Intergenerational inequity: the driving concern, in many discussions of the waste management problem, is intertemporal distribution. Electricity generated from fission is in part consumed in the present, and in part embodied in capital goods which generate service flows running some years into the future. The most durable capital goods we know -- think of the pyramids, an example that has been invoked in this debate -- are short-lived relative to the half-lives of the actinides. The conclusion of this line of argument is then that fission, and waste-generation, are ethically unacceptable in that they impose an inequitable burden of waste management upon future generations.

Given this model, I have no quarrel with the argument nor with the conclusions. My problems are rather with the model itself. In what follows, I am largely concerned with finding ways out of what seems to me to be an overly rigid framework that gives us few or no criteria relevant to the choices among the alternatives we actually face.

Let us begin by listing the elements of the problem that must be brought into a hopefully richer analysis. The first is intertemporal: the waste management problem will extend over many generations. The second is the element of uncertainty in the cost burden being transferred: candidate estimates extend from zero (the case in which we find, tomorrow, an entirely safe and acceptable disposal mode, and employ it) to infinity, the nuclear worst-case. The third element is the tradeoff between the benefits associated with energy production and the risk burdens of waste management. The fourth element, arising from the intertemporal nature of the problem, is the necessity for explicit consideration of the possibly changed preferences -- for example, changes in the preferred mix of energy-related "service" flows and environmental-risk related "disservice" flows -- of future generations.

Are these various elements so difficult to grapple with and bring into a coherent framework that the problem becomes impossible, so that we are thrown back upon the very simple, and unambiguous solution barring any further waste generation? I have no a priori objection to the conclusion, but I do object to reaching it in this way, with no attempt to see how the various elements fit together. And I think the answer to my own question is no: there is such a framework.

For the rough purposes of this section, let us describe it in qualitative terms. Begin with the fourth problem, the one most often considered intractable. It is true that unborn generations cannot be here to represent themselves in decisions taken with respect to nuclear power, but I do not believe that it follows that any decisions taken with respect to nuclear power must necessarily be unethical in the sense of neglecting, or even in the weaker sense of unfairly weighting, their preferences. As a practical matter it is true that many policy decisions, intratemporal and intertemporal, are made under representative arrangements, or with the help of decision criteria aimed at insuring representativeness. The absence of, or in the intertemporal case the impossibility of, direct democratic arrangements is an argument for careful attention to the selection of criteria bearing some decent relationship to those arrangements rather than an argument for a moratorium on discussion of the policy problem.

An analogy with a particular intratemporal policy problem, the problem of income taxation, may be useful here. For much of the debate over the appropriate structure of income taxation has in fact been a debate over how egalitarian the distribution of after-tax incomes should be. Egalitarian objectives have generally been interpreted as supportive of progressive income taxation. But the conceptual underpinnings of this arrangement were always known to be somewhat weak. Those underpinnings, dating to Benthamite Utilitarianism, are unambiguous in requiring the equalization of all incomes across individuals, and therefore marginal tax rates far higher than those presently in place. But perhaps even worse than this gap between the requirements of doctrine and the reality of practice was the flagrant unreality of the behavioral assuptions underlying the calculation: it was tacitly assumed that taxation of earned income had no effect whatsoever on individual work incentives.

Very recently this situation has been considerably clarified, with something like the following conclusions emerging. Suppose that you set out what you think is equitable, in the modified utilitarian sense of stating explicitly what you think is a fair weighting of individual utilities, or even in the sense of stating how you think society should value income accruing to individuals at various income levels, or in the Rawlsian sense of maximizing the income of the worst off individual, or in almost any other explicit sense. Suppose further that you know something about the relationship between taxation and work incentives. Then if the government is to raise a fixed sum, either for expenditures yielding nonallocable benefits or for the accumulation of a surplus or for both, it is possible to calculate an optimal income tax schedule.

The point of the illustrative example is that, given an explicit statement of what fairness means, it is possible to talk about fair policies subject to that criterion: equity resides in the choice of the criterion, here as so often in institutional practice. Our extended description of the income taxation example is motivated by more than a need for this simple moral. For it turns out that the formal analysis of the intertemporal risk problem is mathematically very similar to the analysis of the taxation problem.

A description that formal similarity is compatible with, and coextensive with, a completion of our discussion of the tractability of the remaining features of the intergenerational transfer problem. Uncertainty can be treated, for each individual generation, as it is in the atemporal theory of choice under uncertainty, and indeed it must be so treated to guarantee compatibility with the very simplest consistency properties. The linkage between energy-related consumption services, energy-embodied investment and the risks of energy-related environmental residuals require explicit specification, but given that specification those linkages give rise to no problem of principle. In the simplest case, where we assume either a stock constraint (corresponding to nonrenewable resources) and/or a flow constraint (corresponding to renewable resources), an "optimal and equitable" energy-mix pattern -- the analog of the optimal income tax schedule in the taxation problem -- can be computed.

Any enterprise of this sort is far too simplistic to be taken literally as guidance to best energy policies. Still, we believe it has some merit, in illuminating the structure of the problem of intertemporal risk transfers, and in setting out a framework in which it can be seen whether various sets of advanced assumptions are consistent, and whether the conclusions claimed to follow from those assumptions do in fact follow from them. The more precise specification of these kinds of criteria, and some suggestive remarks on their implications, are at the heart of the next section of the paper.

Criteria and Their Implications

Our objective in this section is the articulation of criteria, or rules of thumb, capturing features of the waste management problem enumerated in the previous section. A prior word on the uses and abuses of this kind of discourse is in order, for its purposes and limitations are often misunderstood. I intend no suggestion that decisions should by made subject only to these, or any other, formal criteria. I believe that formal criteria are most useful in keeping the policy debate "on course," and within the bounds of the feasible. This kind of negative function of policy analysis may be more familiar in an example drawn from a more prosaic field, cost-benefit analysis of water resource projects. There, it never was the case that projects were ruled up or down by their net benefit ranking. But it was true that some of the most inefficient (or negative net benefit) projects were killed in the harsh light of a quantitative revelation of their inefficiency, and our intention is to work here, in similar ways, to devise criteria for distinguishing between relevant and irrelevant alternatives.

There are prior conditions on the kind of disagreements that are potentially resolvable, and on the kinds of arguments that are at least potentially open arguments. I impose upon myself, in our subsequent discussion, some limiting conditions, because I feel that their neglect is at the source of much incoherence. For the sake of emphasis that may amount to overkill, I state an "adequately characterized case" restriction.

Adequately Characterized Case Condition: a discussion of the nuclear waste management must begin with an adequate characterization of the problem. By this we mean that there must be an explicit statement of what the associated risks are believed to be, and some explicit notion of equity -- some way of balancing welfare over the generations.

Is this condition exhorbitant? I do not think so, because these elements are implicit in almost all discussions of the waste management problem, and failure of specification leads only to mutual misunderstanding and confusion. In what follows, several adequately characterized versions of "the" nuclear waste management problem are described and discussed. There are others, certainly more intricate and possibly more realistic. But here we want to show only that something can be done given an adequately characterized case, and a few examples will suffice.

Adequately characterized case 1: pure collective risk: suppose that the nuclear waste management problem is described as a pure intratemporal collective risk problem, with the expected values of health impact assumed known from (for example) a linear dose-effect extrapolation; suppose further that there are no intertemporal effects and therefore no intertemporal distribution problems. The sole remaining problem is then the relative valuation of the health impacts of additional radiation exposure and the costs of reducing that exposure, either through the abatement expenditures for the nuclear fuel cycle or for the incurrence of costs associated with production of energy from higher cost sources. Under these conditions evidence accumulated from the behavior of individuals in risk-related markets is directly relevant, and the relevant comparison is between summed individual valuations of marginal hazard reduction, on the one hand, and total cost of hazard reduction, on the other. If the former exceeds the latter then society is, in the aggregate, probably willing to pay for additional hazard reduction. In the contrary case, society is unwilling to pay for present levels of hazard reduction.

Note that evidence accumulated in one area -- individual choice, among differentially risky occupations -- regarding individual preferences between income and risk has been applied here to quite another set of choices, additional risk from radionuclide exposure. Is this valid? Here we can only put forward a principle, and ask that it be considered.

Principle of Risk Comparability: hazards leading to the same outcomes are similarly (dis)valued, at least to a good enough approximation that evidence is transferable. If this principle is rejected, we can at least ask for an explicit alternative valuation of the hazard.

Alternative "Intrinsic" Hazard Valuation Criteria Problem: If risk comparability is rejected, there must be an alternative valuation of nuclear-related hazards put forward: that is an explicit and consistent valuation of marginal hazard reduction.

In practice, it may in fact be true that actuarially identical nuclear and nonnuclear hazards are differentially valued: because valuations of unfamiliar hazards are generally higher thatn their long-term values, and because of the special anxieties surrounding nuclear power. Still, the comparison we have sketched has its value in compelling explicit recognition of this differntial valuation.

Regarding that comparison, what do the rough numbers suggest? Suppose we take, for an adequately characterized case, one in which actinide releases are the only radionuclide releases associated with the favored waste disposal technology. Suppose further that releases are of the same order of magnitude as normal fuel cycle releases. (These assumptions are arbitrary, as must be any assumptions; we believe they are more plausible than many others, and we invite the reader to redo this or any other calculation with alternative assumptions.) If we take high-range estimates from the literature on the market valuation of individual risks we get estimates of the order of a willingness to pay for marginal hazard reduction of $90,000/1% reduction.

Combined with estimates of total (world population) hazard that are at the outer limits of reasoned pessimism, aggregate willingness to pay for waste disposal hazard reduction is, under these circumstances, of the order of ten million dollars for cumulative hazards from the operation of the American nuclear power industry through roughly 2020. If we divide by, say, 10 for a very crude estimate of year 2020 cost, the figure is one million dollars.

I emphasize what is perhaps obvious, that these are entirely trivial figures in comparison with total power generation costs. Moreover I believe that fancier calculations, so long as they are based upon individual risk valuations as revealed in markets, will not give very different answers. The only way to generate answers higher by the orders of magnitude necessary to sanction the use of emotive words like "enormous" or "catastrophe" is, I believe, to employ highly unrealistic release and transport assumptions.

A corollary conclusion is that a convincing demonstration of a technical alternative for waste disposal characterized by radionuclide releases smaller than, or comparable to, balance of fuel cycle releases, makes the policy discussion manageable. At least two technical disposal alternatives -- deep geologic disposal and mixing with overburden down to natural concentration radiotoxicity levels -- are generally believed to be acceptably safe, and are uncertain only in their costs. Thus comparison of the cost differential between these modes and riskier modes with revealed willingness to pay for hazard reduction forces the question of "nuclear exceptionalism" in hazard evaluation.

Should nuclear-related hazards to be valued differently than other hazards with identical consequences, and if so why? A failure to force this question lies at the root of much of the irresolution in nuclear policy discussions. One implication seems worth drawing, and one comment worth making, before proceeding to the next adequately characterized case. The first concerns the importance of demonstrating some technical waste management alternative with well bounded dispersal risks, even if the associated (internal) costs are fairly high. The comment worth making is that the kinds of quantitative estimates made in the pure collective risk case emerge in other adequately characterized cases: inferred valuations of hazards are generally small, so that reasons for the extraordinary valuations of nuclear hazards must be made explicit for those valuations to be sustained.

Adequately characterized case 2: collective risks and "selfimposed irreversibilities": an adequately characterized case in which the risks involved are the collective risks of radiation exposure, and the irrevesibilities are self-imposed (in the sense that adverse effects are visited only on the decision-making generation), can be analysed in ways similar to our analysis of case 1. The essential differences arise from the necessity of defining the problem as a problem of sequential decision, with the "generation" spanning several "years." Irreversibility can be modelled by assuming that radionuclide releases to the environment in year t are the source of radiation exposures, and thus the source of collective risks from radiation exposures, in that year and thereafter to the end of the time horizon.

Within this framework the kinds of questions that can be posed, and answered with some quantitative precision, turn on the value of the information which may accrue from postponement of a decision to subsequent periods. Suppose, for example, that there are uncertainties in the sequence from radionuclide source to radionuclide receptor, so that there is a plausible range of risk. Suppose further that additional information can, over time, narrow that range: then if we are willing to guess at roughly how much that range can be over time, we can begin to estimate about how much waiting (and how much narrowing) we should do before taking the residual risks in exchange for the benefits of the corresponding activity.

I have no estimates to report. But numerical calculation with similar formulations of sequential decision under irreversibility leads me to believe that it is improbable that narrowing of what the reasonable range of uncertainties could justify postponement of a commitment to the best of the technical waste disposal alternatives, deep geologic disposal. A plausible rationale for the postponement of such a commitment must lie elsewhere: in narrowing the range of disagreement over the cheaper, less certain, modes, so that disposal costs can be reduced.

I hope, in the near future, to be able to produce some estimates of some of these effects, again with no pretense to making "the" decision but simply in the hope of holding discussions within the realistic and meaningful bounds. I might add that, for the nuclear waste problem, there is a whole second area of inquiry into the implications of irreversibility. The focus, in this area, is upon the possibility of changes in individual and social preferences between energy-related goods and services and environmental risk. Under reasonable assumptions -- for example, that higher incomes are associated with increasing aversion to environmental hazards -- there is in principle additional justification for information-generating postponements of a commitment to a disposal mechanism. But here again something quantitative can be said in the sense that any specific assumption about preference changes can be translated into a calculated postponement.

Adequately characterized cases involving explicit considerations of intertemporal equity: here I have no special case calculations upon which to base even a rough judgment of the quantitative implications of the methodology (described earlier in the paper) for these cases. Hopefully a later version of the paper can incorporate such judgments.

Summary and Conclusions

In summary I want to emphasize only some of the general considerations of the paper, and the kinds of conclusions which I believe flow from these general considerations. At the very beginning I would put the necessity for demystifying, and reducing to more familiar terms: the claimed special characteristics of the nuclear waste management problem are, I believe, not unfamiliar in other contexts, where they are routinely accommodated, in both practice and in analytical work.

The second general consideration is a constraint on the kind of discussion that can be helpful: the requirement that cases be adequately specified, in the sense of being conceivably amenable to analysis and comparison with alternative cases. And the third, based upon whatever cases I have been able to push to something like quantitative judgment, is the conviction that, when judged by the standard of revealed hazards, the nuclear-related risks often emerge as negligible. This holds, I believe, across all the hazards of the nuclear fuel cycle (other than proliferation and diversion), that is across all the "nonmalicious" hazards. The implication, I think, is clear: that we should try either to explicitly identify our reasons for our extraordinary valuations of these hazards or, failing that, to scale those valuations down closer, to where we place them when we must, as individuals, pay to validate them.

TECHNICAL IRREVERSIBILITY AND SITE MULTIPLICITY: SOCIALLY-ORIENTED CRITERIA FOR NUCLEAR WASTE MANAGEMENT

by

Gene I. Rochlin

Institute of Governmental Studies
University of California, Berkeley

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INTRODUCTION

There is a consensus that radiologically hazardous wastes from the nuclear fuel cycle should be separated from the biosphere to a sufficient degree and for a long enough time so that they present no significant risk to life. But this consensus does not extend to the definitions of "sufficient," "long enough," or "significant risk." Our ability to predict material or geological stability over the containment times required for long-lived components has been questioned. Moreover, the impossibility of predicting socially relevant factors over such relatively short periods as a few hundred years precludes accurate estimation of either the probability of an accidental or deliberate breach of containment or the effects of such a breach on society.[1]

In the absence of coherent goals or comprehensive regulatory standards, suggested methods of waste management are usually divided into three categories: (1) short-term storage, (2) long-term storage, and (3) disposal.[2] Short-term storage, such as in shallowly-buried metal tanks, requires active maintenance and guarding, and is intended primarily as an interim procedure. Long-term storage, such as emplacement in underground caverns mined in salt, requires little or no active maintenance, but is susceptible to accidental or deliberate breaching of isolation barriers. Disposal, such as ejection into outer space, implies that there are no circumstances that could result in the return of the wastes to the terrestrial environment.[3]

The division of what is properly a continuum of possible waste management methods into three distinct categories is purely arbitrary and appears to have evolved primarily as a way to organize technical thinking in response to political pressures. As each individual waste management method was promoted, heated controversy erupted as to its efficacy. A typical response was to aver that the suggested method was a form of storage, pending the development of an acceptable final disposal scheme. This emphasize the differences between alternative methods rather than the continuity of the problem. The need for perpetual care of a retrievable surface storage facility is difficult to weigh against the probability of re-entry of a space shuttle package or the possibility of an undiscovered water source in a salt formation. In the first case the dominant failure mode is social, in the second case technical, and in the third case informational. Focusing on individual methods and their idiosyncratic deficiencies led to incoherent debate, owing the absence of a shared basis for comparison. The commonality of the goals and objectives of all waste management methods was obscured.

Two criteria, are suggested here, *technical irreversibility* and *site multiplicity*, for use in organizing waste management options in terms of insuring continued isolation from the biosphere in the face of both social and geological uncertainties. They also reflect the possible consequences of technical or judgmental errors. These criteria translate the goals of waste management--public health and safety, ethical and moral responsibilities, obligations to the future, concern over imperfections in present technical and social knowledge--into standards against which the performance of any suggested scheme can be judged. The purpose of the classification is not to substitute quantitative social analysis or purely technical measurements for proper consideration of the ethical and social issues associated with a waste management decision. Rather, it is to provide a clear basis for open and conscious policy choice.

Long-term safety is taken to be the overriding concern. Operational and short-term risks and present costs are held to be of secondary importance in determining an acceptable method,[4] and are to be examined after a desired option has been selected. If this option seems excessively hazardous to present populations, or prohibitively expensive, the next best alternative can then be examined. A minimum ethical requirement is that this choice be made explicitly and self-consciously,[5] and with an open acknowledgement that the well-being of future generations may depend upon our choice. Unexamined or implicit value judgments, ethical choices, and evaluations or risk should be avoided.

CRITERIA FOR WASTE DISPOSAL METHODS

All methods for management of nuclear wastes must take into account long-term risks, short-term and operational risks, and cost.

In principle, these criteria are empirically determined and then used to establish standards (prescriptive norms) for performance that reflect normative judgments as to safety and affordability.[8] The weighing of the relative importance of each of these criteria when formulating standards is a social decision involving both social and ethical values. Nevertheless, there is a persuasive case for the subordination of both immediate risks and present costs to potential long-term hazards when selecting among alternate options for the disposal of long-lived wastes.

Cost is taken to be least important. It is used here not as a technical determinant for defining an acceptable method, but as an elastic boundary condition to be satisfied. Once a method is selected according to consideration of risks, it is then to be examined to determine the social and economic costs of operation. As these costs are unlikely to be prohibitive, the question is what level of safety society is willing to pay for. Affordability is a flexible social and political decision.

A similar argument is made for subordinating short-term and operational risks to long-term ones. The immediate risks of disposal operations will be borne by the same population that benefits from the nuclear power that generates the waste. It can weigh both risk and benefit and make its own decisions. Waste disposal, however, poses a nearly unique problem in that immediate risks and costs may be decreased by exporting risk to other populations, or to the future.[9] There will be a natural desire to minimize present risk and current costs. The only constraints on doing so at the expense of the future are ethical and moral ones.[10]

I suggest that there are two principles of ethical behavior to be followed. The first is to provide the fullest information possible as to long-term risks and future costs.[11] That the future may be unable to act upon this information in no way absolves the present of the responsibility to provide it. If risks are to be exported, a minimum ethical standard is that this should be done openly. The second principle is to act so as to minimize the amount of irreparable harm that could occur as a result of present decisions. It is certain that every action has uncertain consequences for the future.[12] This does not argue against the right to act, but against the refusal to take responsibility for the consequences.[13] The ethical problem of how to balance the needs of the present against the rights of the future, of justifying the export of risks and costs, is far too large to encompass here. Nor is it clear that there exists a basis on which to resolve it.[14] But to act so as to minimize exported risks, particularly when to do so imposes no great burden upon the present, is the minimum ethical requirement.

Therefore, primacy has been given to minimization of long-term risks in establishing a framework for organizing alternatives for waste disposal. If these risks could be precisely determined, the options could be simply ranked. But there are great technical and social uncertainties as to the integrity of waste containment over the long times that must be maintained. An acceptable method for the disposal of high-level wastes must be proof against technical failures such as corrosion of materials, against scientific failures such as overestimating the efficacy of natural barriers to migration, and against geological changes such as glaciers and earthquakes.[15] Few disposal methods can be confidently guaranteed to be permanent over the hundreds of thousands of years that isolation is needed. A more reasonable condition is that, should the containment fail, the time to return the wastes to the environment is of the same order of magnitude as the time necessary for the toxicity to be reduced to a level equal to or below background radiation at a comparable site. Since even the short-lived components of the wastes will remain hazardous over times that are long on social or political time scales, no guarantee of future ability to repair, clean up, or even recognize a breach of containment can be assumed.

The amount of radioactivity in the waste as a function of time can be combined with technical and scientific estimates of the probability of failure to generate a set of numbers that express the long-term risk in terms of the probable material release in any given year.[16] But to translate these into even a rough measure of social impact requires knowledge as to available pathways and population distributions and habits. Such numbers are too imperfect and incomplete in the face of social, technical, and geologic uncertainties to provide useful guidelines for the evaluation of alternative disposal methods. What I suggest in the next section is a method for extending the risk evaluations into a pair of criteria that reflect not only technical paths for returning the wastes to the environment, but also the possibility of active intervention by more or less intelligent beings. As the impacts of a given release cannot be adequately determined for times far in the future, the focus is on minimizing the probability and quantity of a breach of containment in the face of a wide range of uncertainties as to the casual factors.

TECHNICAL IRREVERSIBILITY

I define technical irreversibility as the degree to which emplaced wastes are resistant to recovery or release either by accident or by the deliberate application of technology. Its significance as a criterion is that the more irreversible a waste disposal method is, the more confident we may be that the wastes will remain isolated in the face of social, technical, and geological uncertainties. If technical irreversibility is high, then neither cataclysmic natural events nor the activities of intelligent and technologically adept beings can readily return the wastes to environment.

Irreversibility is propose has a criterion to provide some degree of security against breaching of containment and failure of isolation in the face of unknown social, political, and cultural developments; to provide the greatest possible security against their release or misuse by an agent not equipped to recognize or cope with the dangers. Stability against geological change is a minimum requirement. But the degree of reversibility also depends on the amount of attention that might be drawn to the site by geological features of identifiable artifacts. Intelligent life is notoriously incautious in indulging its curiosity. Construction of a large concrete mausoleum, for example, would almost guarantee that concerted efforts would be made to breach it by intelligent, but uniformed life. On social grounds, such a method is held to be quite reversible. Additional irreversibility cannot be provided by warning messages, symbols, or labels. We cannot assume that even a society that has the technology to undo rather irreversible storage will know enough about radioactivity to proceed cautiously, or that they will be able to decipher a message they cannot read.[17] Indeed, the presence of such an indecipherable message would only arouse additional interest.

Table 1 is a preliminary classification of several waste disposal methods according to the degree of technical irreversibility possessed by each, as derived from consideration of both social and technical factors. The categorization is deliberately broad, since a more precise distinction would not only require more detailed analysis, but is limited by technical and social uncertainty. In addition, many of the suggested waste disposal methods could be made more irreversible by a judicious alteration to provide additional technical or social barriers to prevent breaches of the containment and isolation.

Technical irreversibility, then, is defined by a combination of social and physical elements that measure both the size and the sophistication of the technology or natural mechanism that would be necessary to return the wastes to the biosphere in quantities or at rates that would be radiologically significant. It tends to correlate fairly well with the degree of scientific and technical aptitude that would be required for deliberate waste recovery by a society of intelligent beings, and with the size and cost of the necessary effort. The greater the degree of technical irreversibility, the greater the confidence that any failure of isolation and containment will occur only through the intervention of those fully capable of understanding the risks involved. In that sense, it is a useful criterion for establishing standards for waste management that reflect our ethical obligations to the future.

MULTIPLICITY

There will always be a certain amount of uncertainty as to whether a chosen method for waste disposal is technically sound, or as to whether we are capable of thinking through all possible circumstances by which containment might be breached. If a single site, single technique method is used, an appropriate question is: How strong does your basket have to be before you are willing to place all of your eggs into it? The provision of additional baskets has two dimensions--multiplicity of sites and diversity of options. The purpose is, in either case, to provide redundancy as a hedge against error and uncertainty.[18]

For example, the irreversibility of many types of terrestrial geological disposal methods could be increased by making the number of sites very large, reducing the potential risk due to the breach of any single one. This measure can then be augmented by random emplacement in unrecorded locations. The increased probability of accidental discovery must be balanced against the lower radionuclide inventory to see whether this strategy would in fact reduce net risk under a wide range of geological and social factors. An alterate approach would be to collect many years production of waste into a single giant container and then to emplace this so deeply and with such redundant barriers that any breach seems highly improbable. This approach would significantly increase the probable consequences of a release. Under the specified conditions, multiple emplacement is held to confer more technical irreversibility in the face of uncertainty as to social, technical, and geological futures.[19]

Multiplicity of sites does not, of course, provide any security against fundamental conceptual or design errors. It does help to minimize the consequences of such errors if the failures are random and widely spaced in location and time. But if confidence in the performance of a single site is high, multiplicity does not necessarily provide an advantage on technical grounds. Its primary advantage is the reduction of the consequences of the deliberate or inadvertant action of intelligent life.

Figure 1 locates a number of waste disposal options on a two-dimensional plot that treats technical irreversibility and site multiplicity as independent criteria. The scale of the axes does not imply any attempt to predetermine their relative importance. It must be emphasized that this is a qualitative map. Not only the absolute but sometimes the relative location of any option is a matter of informed judgment. It is not only difficult but unwise to try and localize any method too narrowly. Even if the axes could be accurately and quantitatively labeled, inherent uncertainties in predicting the future would negate any attempt to pin a given method down precisely.

APPLYING THE CRITERIA

If these criteria are to be useful for organizing alternate approaches to nuclear waste management, they must be translatable into normative standards to guide decisions. A central hypothesis as to the utility of the two criteria and two suggestions for applying them to guide the formulation of waste management policy are offered for this purpose.

The hypothesis is that emphasizing the continuity of goals in formulating waste management policy and doing away with arbitrary classifications (such as short-term vs. long-term storage) increases the possibility for reasoned and ethically sound policy choices. The two criteria were developed and the case for them argued here specifically to facilitate this procedure.

The first suggestion is that both technical irreversibility and site multiplicity are desirable goals for waste management. Given equal uncertainty as to whether two different methods for the management of wastes will suffer from gross conceptual or design faults, the one that maximizes an appropriate weighing of the two criteria is preferable. Although estimating the relative weights is a part of the decision process not be preempted here, Fig. 1 suggests how this might be done. The further into the upper right hand corner a method lies, the greater the reduction of potential future risks in the face of social, technical, and physical uncertainties. Conversely, the greater the confidence in social and physical stability over the time scale during which the wastes must be kept isolated, the closer to the lower left an acceptable method will lie.[20] Note that this method is applicable to all forms of waste.

The joint application of the two criteria provides a crude measure of reduction of risk in the face of uncertainty. But uncertainty increases with time. Using Fig. 1 as an illustrative device, there is an effective containment time scale running from the lower left (reversible, single site) to the upper right (very irreversible, high multiplicty). The shorter lived the waste, the less the necessary containment time, and therefore the more uncertainty that can be tolerated.

This leads to the second suggestion: for any type of nuclear waste, a set of combinations of the two criteria can be determined that bonds the region of acceptable waste management methods. Referring once again to Fig. 1, this suggestion can be graphically interprered as saying that there are lines of equal preference that can be (fuzzily) drawn upon the diagram to separate the acceptable from the unacceptable regions of performance. As minimization of long-term risk is the dominant concern, the desirability of any given option will be measured by the degree to which it lies beyond the region of minimum acceptability. If there are several equally preferable options, the secondary criteria of reducing operational risk and cost can be freely used to select among them.[21]

It should be kept in mind that technical irreversibility is meant to provide a criterion for choice and not to preempt it. Complete irreversibility that precludes all possibility of recovery may not be the most desirable outcome. It can be argued that our obligation to the future extends to the preservation of options as well as the prevention of harm, that we have an obligation to try to avoid irreversible consequences of our actions.[22] It may then be considered more desirable to dispose of the wastes by a method roughly as irreversible as the dispersal of uranium in present ores. This would at least partially correct the irreversible depletion of natural supplies of fissionable material. The provision of an artificial ore bed is intended to make these materials accessible only to those who understand what they are mining and why. In that regard, the artificial beds could be somewhat more secure against accidental mining than natural beds have been if care is taken to make sure that the wastes are not co-located with other desirable minerals.

On Fig. 2, a locus of minimum acceptability has been plotted, using the same axes as Fig. 1.[23] Assume that this represents emplacement roughly as hazardous as presently mined uranium ores. A second curve has been drawn at somewhat higher values of irreversibility and multiplicity, prepresenting emplacement that is not beyond potential recovery but would entail considerable cost and effort using present technology. Nevertheless, the wastes could be recovered if the need or desire were great enough. By selecting a waste disposal option that lies between these two limits, we could do our best to ensure that the future would be exposed to no more risk than if we had not used the ore for power at all, while still doing our utmost to avoid irreversibility foreclosing future options.

DIVERSITY OF OPTIONS

In the past, waste management policy has consistently been drawn to the search for the single most desirable alternative. The method suggested here facilitates the pursuit of several equivalently desirable options. To return to the previous metaphor, it is of little avail to put your eggs in many identical baskets if they all fail at once. Diversity of options can provide protection against such gross failures.

As with multiplicity of sites, statistical reasoning alone does not necessarily lead to the conclusion that diversity of options reduces risks.[24] The parallel pursuit of more than one method for waste management is an explicity normative recommendation, based on the ability of intelligent life to respond to failures. If one of the disposal methods should fail at a time when there is a society capable of understanding what has happened and taking remedial action, it would be extremely important to have at least one alternate storage method that is trusted and immediately usable. If a method has been chosen that has fairly high site multiplicity, and if not all sites fail simultaneously, it is even possible that the transfer could be effected before any large fraction of the stored wastes would be released.

If the impact of any single release is potentially catastrophic, it might be preferable to hold to a single waste disposal method to maximize the probability that no untoward events at all will occur during the required storage period. But a properly chosen combination of several multiple-site options would ensure that even a worst case event would not be catastrophic, particularly for a method with high irreversibility. Furthermore, a most careful monitoring and testing program should be an integral part of waste management procedures to keep track of the condition of the sites and detect early signs of imminent failure.

This social safeguarding will surely not outlast knowledge of the sites, and will not, therefore, compromise their long-term integrity. It is needed because the highest risk would be from gross failure in the early years of storage, and technologies that do fail are likely to give early warning signs. This should not be only a monitoring procedure, but part of an ongoing program of technical and social research to search for and identify procedures and techniques that would increase site integrity and further minimize both the degree and the consequences of uncertainty. Our obligation to the future is not discharged simply by determining the level of risk to which they will be exposed.

An ethically sound waste management policy will continuously and determinedly seek methods to reduce that risk.

CONCLUSION

Two criteria--technical irreversibility and site multiplicity--have been suggested for use in establishing standards for the disposal of nuclear wastes. They have been constructed specifically to address the reduction of future risk in the face of inherent uncertainty as to social and political developments over required waste isolation times, to provide for safe disposal without requiring a guarantee of future ability to recognize, detect, or correct errors and failures.[25]

Decisions as to how to apply or weigh these criteria in conjunction with other waste management goals rest ultimately with societies and their governments. My purpose has not been to preempt this process, but to construct a framework that facilitates consideration of its ethical and normative components. As with many other human activities, the production of nuclear power entails consequences and risks for future generations who can have no voice in present decisions. On that account, their welfare must be carefully considered. It is not within our power to pass on to the future a world unchanged by our residence in it. Nor do we have an obligation to do so. But, as our every act has the potential to profoundly alter future lives, our minimum ethical obligation is to examine most thoroughly the potential consequences of present actions, to acknowledge them openly, and to minimize the potential for irremediable harm.

NOTES

1. By "society" is meant both intellignet life and its organised activities. The social costs of evacuatin and contaminatin of land, as well as the effort needed to relocate and decontaminate are rarely assesed in computing the effects of radiological accidents.

2. The distincition is that wastes are in principle retrievable from storage, but not from disposal. Recent documents such as U.S. ERDA, Alternatives for Managing Wastes From Reactors and Post-Fission Operations In The LWR Fuel Cycle, (ERDA-76-43, NTIS, Springfield, VA., 1976), have discontinued the confusing use of the term "ultimate storage" for disposal.

3. ERDA-76-43 (3) classifies transmutation and space disposal as "elimination" to distinguish them from terrestrial disposal. This introduces another new category and suggests that other disposal is not "ultimate."

4. In the November, 1975 report of a survey conducted by the Human Affairs Research Center of Battelle Memorial Institute, the attitudes of 465 persons from five regions in the United States towards waste disposal were analysed by means of a poll. The respondents were then aggregated into six groups: environmentalists; high school students; nuclear technologists; public utility employees; university students; church and civic group members. The opinions of five of the six groups

were in agreement with the rank ordering by importance suggested here. Only the nuclear technologists rated short-term above long-term safety. All groups rated costs as being the least important consideration.

5. That is, an action is a candidate for moral choice only if it is voluntary and based on all available information. See, for example, Aristotle, *Nichomachean Ethics*, Book III, Sections 1-5.

6. I follow here the general outline of the analysis by W. W. Lowrance, *Of Acceptable Risk* (W. Kaufman, Inc., Los Altos, Cal., 1976).

Matters of empirical fact are:

Risk--the measure of adverse effects;

Efficacy--the measure of beneficial effects;

Cost--both internalized and external;

Distribution of the above.

These translate via personal and social values into normative measures:

Safety--the degree to which risks are acceptable;

Benefit--the degree to which efficacies are desirable;

Affordability--the degree to which costs are reasonable;

Equity--perceptions of just distributions.

Criteria are taken to be based upon empirical data. They provide only the quantitative basis for choice. Standards are used to screen for acceptability, and therefore are based on the normative factors. Thus the maximum permissible concentration for a given radionuclide in air or water may be expressed in empirical terms such as (Ci/m^3), but are determined both by pathways to life, and by decisions as to safety and equity that are not entirely based on technical data.

7.. With the exception of the civil liberties implications of either successful operation or of failure have rarely been considered in analysing the nuclear fuel cycle. Among the factors that need consideration are patterns of employment and land use, the consequences of evacuations and other dislocations, and anxieties and fears raised by both real and potential accidents. See, for example, R. Budnitz and J. Holdren in Annual Review of Energy 1 (Annual Reviews Inc., Palo Alto, 1976).

8. There appears to be widespread agreement by all parties that operating costs for any presently conceivable waste management method will be so small, on a percentage of power costs basis, that safety considerations should predominate in the decision. See also (5).

9. It is assumed here that nuclear electric power is a common good--one that distributes its benefits over all persons in

a society by virtue of their participation in it--as well as a private one. Similarly, the risks and costs of waste management may be described as common "bads." In this context, exporting risk means exposing persons who derive neither individual nor common benefits. These may be persons in the future or members of other contemporary societies.

10. M. P. Golding and D. Callahn, "What is Our Obligation to Future Generations?", Working Paper Series, #2 (Hastings Center Institute of Society, Ethics, and the Life Sciences, Hastings-on-Hudson N.Y., 1972).

11. K. Arrow, "Social Responsibility and Economic Efficiency, "*Public Policy XXI*, 303 (1973). Arrow argues that provision of full information as to potential costs and risks is the minimum eithical obligation of the seller. H. Jonas (*17*) argues further that modern technology has conferred the power to have such enormous impacts that traditional ethics will not suffice. Given that uncertain outcomes can destroy the very context in which ethics operates, ignorance can no longer serve as an alibi. The ethical obligation thus extends to making the search for knowledge a prime duty.

12. "Action" is used here in the sense of H. Arendt. In contrast to labor and work: "Action, the only activity that goes on directly between men....corresponds to the human condition of plurality, to the fact that men, not Man, live on the

earth and inhabit the world. While all aspects of the human condition are somehow related to politics, this plurality is specifically *the* condition....of all political life." *The Human Condition* (University of Chicago Press, Chicago, 1958) at p. 7. To act is to set something into motion in the context of human plurality, and because of this plurality every action is a beginning whose process is irreversible and whose outcome is unpredictable.

13. The future is by definition uncertain. Attempts to find a substitute for action and avoid the frustration of unpredictable outcomes must lead to either the suppression of human plurality through tyrannical control or the insistence that one's activity is "worldly" or self-contained, rather than political and interactive. The former reflects the refusals to allow consequences, the latter the refusal to acknowledge them. See H. Arendt (13) Ch. 5.

14. J. Honas, "Technology and Responsibility: Reflections on the New Task of Ethics," *Social Research* *40*, 31 (1973). See also, H. Arendt (13) at p. 232.

15. Imperfections in human knowledge and the fundamental uncertainties associated with the probilistic distribution of the frequency and severity of cataclysmic events can be somewhat compensated for by the provision of secondary barriers that ensure slow

diffusion and return of the wastes to the environment even if the primary containment is breached.

16. This much, at least, is within the scope of mathematical risk analysis.

17. Arthur Evans excavated the first of the Mycenaean tablets inscribed in Linear B at Knossos in the year 1900. More than 50 years elapsed before they were deciphered. See J. Chadwick, The Decipherment of Linear B (Cambridge University Press, Cambridge, 1970). The 3,500 years that have elapsed since the inscriptions were made is only about one-seventh of the half life of Pu-239. Yet, almost all the formation as to the culture and language of Minos had been lost.

18. M. Landau, "Redundancy, Ratinality, and the Problem of Duplication and Overlap," Public Administration Review 29, 346 (1969).

19. More detailed method-specific analysis is needed to examine this somewhat intuitive conclusion.

20. It should be kept in mind that Fig. 3 is a conceptual and heuristic device, not a quantitative map. The significant information is the relative, not the absolute, position of any given option.

21. This is, of course, only one of the possible ways to select an option. The major point here is the bounding of a region that contains the unacceptable methods, so that they may be discarded.

22. D. E. Boeyink, "Finitude and Irreversibility: The Duty to Avoid Irreversible Consequences," ms. presented at an AAR regional meeting, April 1975. Irreversible consequences are to be distinguished from irreparable harm. The former involves uncertainty as to the harm or good our actions in the face of imperfect knowledge and a moral finitude. Note that it is the irreversibility of consequence that is suggested as being avoidable. All action is inherently irreversible. But see H. Arendt (13).

23. Waste disposal methods have been deliberately omitted from Fig. 4 to avoid even the appearance of preempting social choice. The placement of the indicated regions relative to the various options is not purely a technical problem.

24. Assume that all methods chosen have equal rates from a failure. If two options are selected, and the probability of a certain release during the required storage time is 1/2 for each of the methods, the probability that both will have such a release is 1/4. For three methods, the probability would be 1/8. This is advantageous only if the release in question is small enough so that this constitutes effective dama For two methods, the probability decreases to 3/4, and for only one method to 1/2. For any combination of methods there will be a distribution of failures in time and a distribution

of radionuclide inventory. It would be most irstructive to have some strategies played out by mathematical analysis to examine over what period the hazards entailed are actually increased by diverse options in the absence of remedial action. For long times, damage limitation is expected to dominate.

25. To the extent that one holds the contrary belief that social stability is more assured than present technological aptitude, it would be better to store the wastes in a small number of accessible sites so that perfomrance could be monitored and errors corrected. Of course, this assumes that future technologies will be an improvement and that operational errors, such as the problems that have occurred at the Hanford reservation, described in Creating Energy Choices for the Future (ERDA-48, U.S. GPO, Washington, D.C., 1975, Vol. II, p. 119), will be avoided.

TABLE I

TECHNICAL IRREVERSIBILITY OF SELECTED METHODS FOR THE MANAGEMENT OF HIGH-LEVEL WASTES

DESCRIPTIONS ADAPTED FROM ERDA-76-43 (5)

Disposal Method	Physical Irreversibility	Social Irreversibility	Technical Irreversibility
Retrievable surface storage	very low for water cooling to moderately low for above ground convection cooling	very low	very low
Sealed Mausoleum	low to moderate	very low	low to very low
Mined caverns in salt	moderately low	low	low
Drilled or solution mined cavities in salt	depends on ground water; low to moderate	low for domes to moderate for bedded salt	low to moderate
Seabed, emplacement in bottom sediments	moderate, depends on	moderate to moderately high	moderate to moderately high
Mined rock cavity, partial melting	moderately high	moderate to moderately high, (away from other minerals)	moderate to moderately high
Mined rock cavity complete melting	moderately high	moderately high (away from other materials) high	moderately high
Seabed emplacement in basement rock, no melting	moderately high to high, depends on geologic activity	high	moderately high to high
Deep rock melt, drilled hole	high; depends on geologic activity	high (located away from other minerals	high
Deep rock melt, self-descending capsule	high to very high, depends on geologic activity and sinking depth	high to very high	high to very high
Space disposal, outer space mission	very high to complete	very high to complete	very high to complete
Transmutation	complete	complete	complete

TABLE 1

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Seabed, emplacement in bottom sediments	moderate, depends on nature of sediments	moderate to moderately high	moderate to moderately high
Mined rock cavity, partial melting	moderately high	moderate to moderately high, (away from other minerals)	moderate to moderately high
Mined rock cavity, complete melting	moderately high	moderately high (away from other materials)	moderately high
Seabed emplacement in basement rock, no melting	moderately high to high, depends on geologic activity	high	moderately high to high
Deep rock melt, drilled hole	high; depends on geologic activity	high (located away from other minerals)	high
Deep rock melt, self-descending capsule	high to very high, depends on geologic activity and sinking depth	high to very high	high to very high
Space disposal, outer space mission	very high to complete	very high to complete	very high to complete
Transmutation	complete	complete	complete

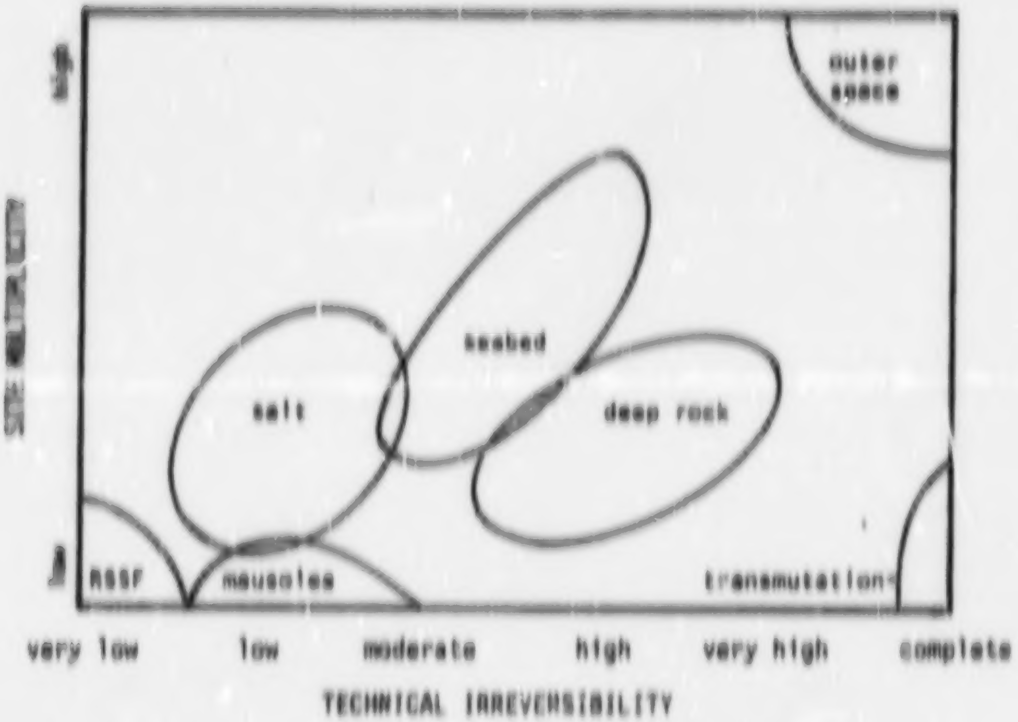
high
SITE MULTIPLICITY
low
outer space
seabed
salt
deep rock
RSSF
mausolea
transmutation
very low
low
moderate
high
very high
complete
TECHNICAL IRREVERSIBILITY

Figure 1

Various waste disposal methods classified by site multiplicity and technical irreversibility. For an explanation of the criteria see Table 1. The salt and deep rock categories as displayed on this figure include all of the various methods for these geological formations.

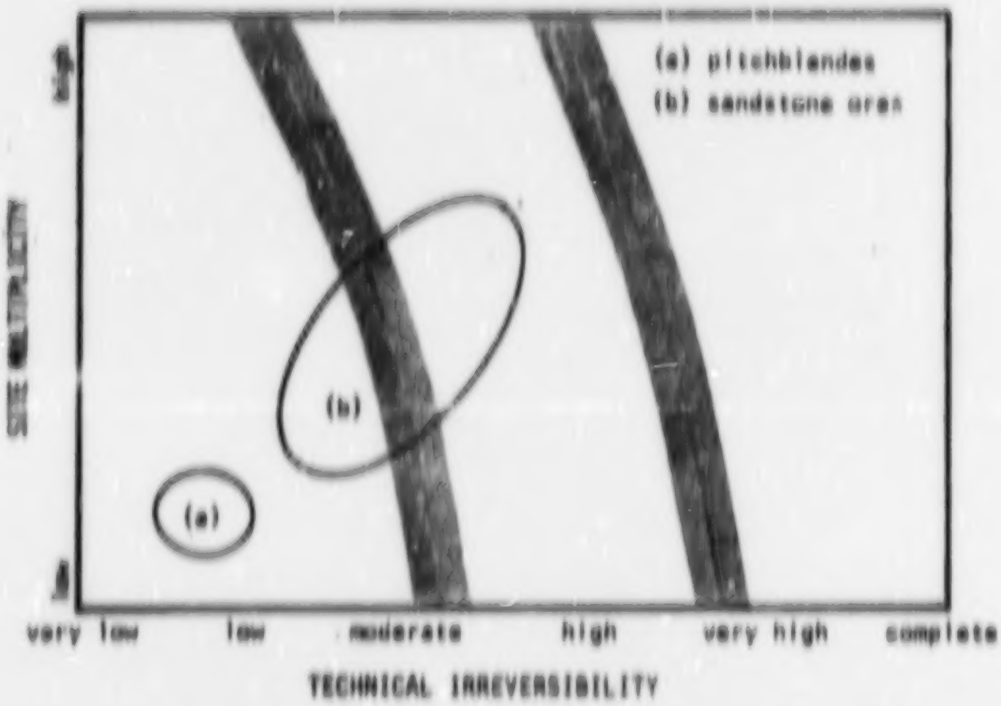

Figure 3

A suggestion for loci of equal preference in choosing among alternative methods for disposal of nuclear wastes. The curve at lower values of irreversibility approximates roughly the natural emplacement of presently mined 0.2% sandstone U ores. The two types of ore, various sandstones and 40%-60% pitchblendes, are indicated on the figure for purposes of comparison.

INSTITUTIONS FOR EFFECTIVE RADIOACTIVE WASTE MANAGEMENT

BY

MASON WILLRICH
Director, International Relations
The Rockefeller Foundation

Paper prepared for delivery at the Conference on Public Policy Issues in Nuclear Waste Management, Chicago, Illinois, October 28, 1976.

Post-fission radioactive waste is highly toxic for extremely long periods of time--at least thousands, perhaps hundreds of thousands of years. Whether optimists or pessimists, as we look to the future, we share an expectation that the vital imperatives of military security and energy supply will surely result in the creation of rapidly growing volumes of radioactive waste in the United States. But is it right to continue activities which generate radioactive waste when a safe method for permanent disposition has not been fully demonstrated?

An optimist may deny there is a serious problem because time and money will provide technology for a variety of solutions. A pessimist may deny there is a solution because--sometime, somewhere--man-made or natural cataclysms will inevitably breach any technological containment, and toxic radioactive waste may then spill or seep into the biosphere.

The risks posed by radioactive waste must be viewed in context and balanced against the benefits to be derived from activities which produce the waste and the consequences if those activities were stopped. Our security as a nation appears to rest in part on our nuclear deterrent, and the well-being of every society depends on adequate energy. The world urgently needs practical alternatives to fossil energy, and nuclear fission has been demonstrated to be a practical way to generate electricity.

I am currently in the final stages of completing a report to the U.S. Energy Research and Development Administration (ERDA) on radioactive waste management and regulation. The study was conducted under the auspices of the Energy Laboratory of the Massachusetts Institute of Technology.

Our report focuses on the management and regulation of post-fission radioactive waste generated in the U.S. This includes so-called high-level and transuranic contaminated low-level (TRU) wastes. The purpose of the report is to assist in developing governmental institutions which are necessary for the safe management of radioactive waste, currently and in the long term. Indeed, an underlying hope is that our work will accelerate such organizational development within the U.S. government. Today, I would like to discuss with you our principal conclusions and recommendations, which are still tentative.

* * *

Let me begin by describing the main features of the current government organization for radioactive waste management and regulation.

The safe management of post-fission radioactive waste is already a present necessity and an irreversible long-term commitment.

A rapidly growing number of spent fuel assemblies are accumulating in temporary storage pools at commercial nuclear power plants, pending a government decision on whether to authorize reprocessing.

If commercial reprocessing is not authorized, the spent fuel must be safely managed indefinitely. A relatively small volume of high-level waste is being stored temporarily in tanks adjacent to a privately owned reprocessing plant that is now shut down. Commercial TRU waste has been disposed of previously in relatively small amounts at various shallow land burial and ocean dump sites.

However, existing military waste will constitute a much larger and more difficult management problem in the near future than the wastes being generated by the commercial nuclear power industry. A large and still growing amount of military high-level waste is being temporarily stored in tanks. No specific plan or schedule for treatment and permanent disposition of this waste has been made public. Rough estimates of the cost of preparing the existing inventory of military high-level waste for safe permanent disposition run as high as $20 billion.

The basic goals of U.S. radioactive waste policy are unclear. The basic technological criteria for permanent disposition of commercial high-level waste are containment and isolation from the biosphere for as long as necessary to prevent it from being or becoming a harmful source of radiation. The basic technological goal regarding TRU waste is unclear and undecided, although if commercial reprocessing is authorized, the quantities of plutonium contained in this category of commercial waste will be comparable to the plutonium quantities in high-level waste.

The technological criteria for military high-level and TRU waste management are unclear. Some critics fear that surface tank storage of already solidified high-level waste will become a permanent disposition of existing volumes.

In general, radioactive waste policy contains no explicit criteria to apply in developing institutional arrangements for waste management and regulation. Yet institutional effectiveness is an essential ingredient of safe management.

The existing organization for radioactive waste management is likely to be unworkable if left unchanged. The management of commercial high-level waste is presently divided between private industry and the federal government. The private sector is responsible for temporary storage, treatment, packaging, and transport, while ERDA is responsible for permanent disposition. Bifurcated responsibility for the series of waste management operations which are technically and functionally integrated creates incentives for each sector to pass through to the other as much as possible of the risks and costs. Moreover, in such a framework, underlying trade-offs between short- and long-term considerations are difficult to make. The existing structure thus tends to prevent, rather than to facilitate, the efficient management of commercial high-level waste.

All management functions for commercial TRU waste have rested with the private sector until now. Proposed Nuclear Regulatory Commission (NRC) regulations, however, would shift the task of permanent disposition to ERDA. Collection, temporary storage, treatment, packaging, and transportation would continue to be managed by the private sector.

ERDA is responsible for all stages in the management of most military high-level and TRU wastes. Most operations are conducted for ERDA by private contractors.

In the case of both commercial and military high-level waste, permanent disposition is authorized only at a federal repository on federal land. State land use regulation of the location of permanent repositories for high-level waste is thus ultimately preempted by federal law. Nevertheless, a state government may effectively oppose, through political means and legal procedural delays, attempts by the federal government to establish a federal repository within its borders without its consent.

The existing framework for radioactive waste regulation is likely to be ineffective if left unchanged. NRC has primary, comprehensive authority to license commercial high-level and TRU waste operations from temporary storage through permanent disposition. However, NRC has relinquished regulatory authority over TRU waste to certain states. State regulation has been ineffective in some instances. The Department of Transportation has concurrent regulatory authority with NRC over the transport of radioactive waste.

NRC has authority to license the permanent disposition of military high-level waste, but lacks authority to license the temporary storage and treatment of such waste. NRC has no licensing authority over military TRU waste. Therefore, no independent regulatory agency licenses existing military post-fission radioactive waste to assure the public health and safety. Nevertheless, military high-level and TRU wastes constitute the vast bulk of those in existence, and incidents have occurred which have raised doubts about the safety of ERDA's military waste management operations.

Ocean disposal of high-level waste is prohibited by U.S. legislation and international law, and ice sheet disposal in the Antarctic is prohibited by the Antarctic Treaty. The Environmental Protection Agency (EPA) has concurrent jurisdiction with NRC over ocean dumping of TRU waste, although all such U.S. activity has been suspended.

The federal scheme of regulation basically preempts state safety regulation. State land use regulation may, however, operate to affect the location of all radioactive waste operations, except permanent disposition of high-level waste at a federal repository. The location of such a repository is a federal matter which ultimately preempts state law. However, as noted above, political and procedural means are available for state opposition.

Pervading the entire framework for radioactive waste regulation are two further features: (1) EPA is responsible for developing generally applicable environmental standards for radiation protection; and (2) the National Environmental Policy Act (NEPA) requires a particular procedure, including preparation of an environmental impact statement, for major federal actions regarding radioactive waste management and regulation.

A major area of regulatory uncertainty concerns whether NRC has authority to license ERDA demonstrations of methods for permanent disposition of high-level waste. Such demonstrations, though on a small scale, may be potentially hazardous in themselves. They may also create momentum for rapid expansion into a full scale operation.

What steps should we take to strengthen the capacity of our governmental institutions to deal effectively with the radioactive waste problem? Our report recommends consideration of the following institutional reforms in order to deal more effectively with post-fission wastes:

First, U.S. radioactive waste policy goals should be clarified to include institutional criteria. Important criteria would be:

--strong built-in management incentives;

--clear differentiation of management, regulation, and research and development functions;

--ample jurisdiction for each functional component to perform all interdependent operations within an area of responsibility; and

--adaptability to a changing social environment.

Second, a national Radioactive Waste Authority should be established as a federally chartered public corporation. The Authority would manage all high-level and TRU wastes under U.S. jurisdiction or control.

The Authority would be independent of ERDA. It would be governed by a board of directors composed of members drawn from government, nuclear industry, the academic research community, and the general public. Except for ERDA research, development and demonstration activities, the Authority would own all high-level and TRU waste facilities in the United States. This would include facilities for temporary storage, treatment and permanent disposition of waste, and any specially constructed waste transport containers. The Authority would take over existing commercial and military waste facilities.

The Authority would be self-financing. It would issue bonds and recover the full costs of providing waste management services from its customers. It would be authorized to conduct waste management operations itself or to contract with private industry for the conduct of such operations.

The Radioactive Waste Authority would thus be intended to provide comprehensive, integrated, efficient management of both commercial and military high-level and TRU wastes. It is noteworthy that the Royal Commission on Environmental Pollution has made a comparable recommendation for establishment of a national nuclear waste disposal corporation in Great Britain.

Third, with NRC as the primary agency, a comprehensive regulatory framework should be established to assure the safety of all radioactive waste management operations under U.S. jurisdiction or control. All high-level and TRU waste operations, whether involving commercial or military waste, would be subject to NRC licensing. Licensing would be required of existing (unlicensed) military wastes, as well as future commercial and military wastes. Various categories of waste from diverse sources may be regulated differently in appropriate circumstances, but all regulation would occur within a unified framework, headed by NRC. Other interested federal and state agencies would play advisory roles.

Fourth, ERDA should continue to have primary government responsibility for research, development and demonstration of radioactive waste technology. That responsibility would, however, be separated from management, of industrial-scale operations on the one hand, and regulation, on the other. ERDA - supported radioactive waste research, development and demonstration activities would be coordinated with and responsive to the needs of both the NRC and the proposed national Radioactive Waste Authority.

Fifth, the U.S. government should propose than an international Radioactive Waste Commission be established under the International Atomic Energy Agency (IAEA). International approval would be required for any disposition of high-level or TRU waste which would result in emplacement beyond the limits of national jurisdiction. The IAEA Commission would also review and comment on proposals for permanent geologic disposition of high-level or TRU waste within national jurisdiction.

Finally, it is important to consider the problems of transition from the existing situation to what we have proposed. The recommendations are not especially sensitive to future scientific revelations or technological developments. While some of them may appear to be quite far-reaching--especially those regarding a new structure for radioactive waste management--it is important to recall that they can be implemented in most instances with little, if any, impact--welcome or resisted--upon large vested interests.

Since research, development, and demonstration would remain ERDA's task, the Radioactive Waste Authority could be launched without any delay in ERDA's plans for radioactive waste demonstration projects. For example, the establishment of an independent Radioactive Waste

Authority would be compatible with, and could indeed provide additional impetus for, ERDA demonstration of long-term disposition techniques and also an early ERDA demonstration of high-level waste solidification at the Allied-General Nuclear Services facility at Barnwell, South Carolina.

* * *

There is today no long-term management of radioactive waste, no comprehensive scheme for regulation of such waste, and no commercial reprocessing industry in the United States. I believe that institutions can be developed which will provide reasonable assurance of safe management of radioactive waste in the U.S. and elsewhere in the world. We have an opportunity to do so now, but may well be our last clear chance.

Nuclear Waste Management: Problems of Organization in the Federal/State System

By: William O. Doub, Esq.

LeBoeuf, Lamb, Leiby & MacRae
1757 N Street, N.W.
Washington, D.C. 20036

Nuclear Waste Management: Problems of Organization in the Federal/State System

Management of radioactive wastes is one of the most serious generic problems facing the nuclear industry today and as such poses a distinct challenge to our federal system of government. It is all too evident that this challenge in decisionmaking has not been met and consequently the problem is worsening to the point of threatening the continuation of the nuclear industry. This paper examines that problem from an institutional point of view -- i.e., the interfacing of different levels of government in the management of radioactive wastes -- and suggests a redefinition of governmental interests to meet that challenge within our existing federal structure of government.

I would like to make it clear at the outset that I will primarily be discussing federal-state relationships as they affect low-level waste management; for this is an area where there exists both experience and a demonstrated need for rethinking old solutions.

Radioactive wastes are those wastes that have been contaminated or possibly contaminated by radioactive isotopes. These wastes may be broadly categorized into high-level, transuranic-contaminated low-level,[1] and non-transuranic-contaminated low-level. Low-level radioactive wastes are generated primarily by commercial reactors and consist of spent fuel elements, discarded hardware, solidified radwaste and assorted irradiated residue. The balance of low-level radioactive wastes come from hospitals, laboratories and universities. Non-transuranic-contaminated low-level radioactive wastes do not require excessive shielding or extensive isolation and can be disposed of safely by shallow land burial. Currently low-level radioactive wastes are being stored at six domestic commercial disposal facilities[2] under the exclusive regulatory jurisdiction of the Nuclear Regulatory Commission or concurrent with the states under the Agreement State Program.

High-level waste is composed of hundreds of radioisotopes ranging from trace quantities to very high concentrations and from short to long half-lives. High-level wastes are presently being generated by military activities and various governmental research efforts.

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[1] Transuranic means having an atomic number greater than uranium, e.g., neptunium, plutonium, americium, curium. Although transuranic-contaminated wastes contain radioisotopes in much lower concentrations than in high-level radioactive wastes, these elements have long half-lives and are therefore potentially troublesome.

[2] These facilities are located in Beatty, Nevada; Maxey Flats, Kentucky; Hanford, Washington; Sheffield, Illinois; West Valley, New York; and Barnwell, South Carolina.

When the commercial plutonium reprocessing cycle is authorized, it will also spawn high-level wastes which will then be solidified. Under present regulations high-level wastes are delivered to federal repositories for long-term management under the administration of the Energy Research and Development Administration. Mill tailings, fuel manufacturing activities, and decommissioning of nuclear facilities are additional sources of both low and high-level radioactive wastes.

Low-level nuclear wastes are being generated at a steadily increasing pace. By the end of 1976 it is currently estimated that there will be over 13 million cubic feet of low-level radioactive wastes.[3] In the last five years alone, 1 to 2 million cubic feet of low-level radioactive waste have been generated and this is expected to increase to 14 million cubic feet per year between 1980 and 1990.[4] By the year 2000, low-level radioactive wastes accumulated by the nuclear power industry, even with plutonium recycle and a liquid metal fast breeder reactor and exclusive of decommissioning wastes, will average between 330 and 350 million cubic feet.[5] This estimate includes 5.4 million cubic feet of transuranic-contaminated waste.[6/] Military wastes alone will contribute something in excess of 11 million cubic feet. For comparison purposes, the wastes produced from the nuclear program will be considerably less than those produced during the same time period by coal-fired generating units employing scrubbers.

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[3] Hearings on low-level radioactive waste disposal before the House Conservation, Energy and Natural Resources Subcommittee of the Committee on Government Operations, 94th Cong., 2d Sess. at 218 n. 2 (1976).

[4] Comptroller General of the United States Report to Congress, "Improvements Needed in the Land Disposal of Radioactive Wastes -- A Problem of Centuries" (RED 76-54) (January 12, 1976), at 5, n. 6.

[5] Hearings on Radioactive Wastes before the Joint Committee on Atomic Energy, 94th Cong., 1st Sess. 32, n. 43 (November 19, 1975).

There are a number of reasons that can be given as to why disposal of radioactive wastes has not received the attention from both the nuclear industry and the government it should have until now. There is no existing commercial market for the byproducts of nuclear fission. This must await authorization of the commercial mixed-oxide fuel cycle. Even then, as noted previously, plutonium recycle will create a residue of wastes without present commercial value. There is also a sharp dislocation between the benefits of producing these wastes -- i.e., nuclear power generation -- and the costs of disposing of them which makes it difficult to apportion these costs

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[6/] Joint Atomic Energy Committee Hearings, supra at 32, n. 13.

along the fuel cycle.[8] There has been, therefore, no real economic incentive to settle upon a solution of both the technological and regulatory problems associated with the management of these wastes. In the case of the nuclear generating industry technological solutions immediately translate into dollars saved.

Balanced against historical and even current government and private inertia is increasing public concern about the effects of radioactive wastes on mankind now and in the future. The public is quite properly concerned about the irreversibility of decisions regarding the management of radioactive wastes and about the ability of political and social institutions to deal with this problem for the centuries currently required. This concern, which to a large degree is fueled by lack of knowledge, is reflected in proposed moratoria, rulemaking petitions, public interventions and state legislative activity directed toward restricting or stopping waste disposal by one means or another.[9]

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[8] See "Petition of the Natural Resources Defense Council to Adopt Interim Regulations Governing Disposal of Low-Level Radioactive Wastes," dated August 9, 1976, in which petitioners propose that fees be assessed against the producers of transuranic-contaminated wastes.

[9] The Kentucky excise tax, discussed later in this paper is an example of such activity.

Many papers have been written on the various technologies for disposal of these wastes ranging from containment or geologic isolation to removing the wastes from the environment by such esoteric and presently impractical solutions as terrestrial ejection by rocket or by transmutation. The latter method holds the promise that when nuclides are bombarded by nuclear particles or radiation the bombarded nuclides will be converted to new species that will decay more quickly or emit less hazardous radiation. It would be presumptuous for one with predominantly legal training to examine the viability of those technologies here. But it can be presumed that a technological solution for the ultimate management of these wastes will be selected in the very near future. The immediate challenge, therefore, facing both the nuclear industry and the government is to fashion today social and political institutions which can administer the wastes presently and prospectively produced without reliance on future scientific "breakthroughs."

Currently, the regulation of radioactive waste disposal is shared by a multitude of federal and state agencies. At the federal level there are at least five such agencies which seek to exercise jurisdiction over portions of the problem.

The Energy Research and Development Administration (ERDA) is responsible for developing an environmentally safe waste management technology and for establishing and managing federal radioactive waste repositories. With regard to the first responsibility and in accordance with a directive from the Joint Committee on Atomic Energy, this year ERDA issued a report entitled "Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle" (ERDA-76-43). This document will be followed by an environmental statement, scheduled to be released in draft by the spring of 1977.[10] Comments on ERDA-76-43 will be considered in the preparation of the environmental statement.

With regard to ERDA's second area of responsibility, the agency plans to develop a pilot facility capable of receiving and storing high-level wastes by 1985. This facility will be licensed by the Nuclear Regulatory Commission. ERDA also owns and operates burial grounds for waste generated by its own research facilities as well as by military activities. ERDA is currently evaluating operations at these facilities and is expected to propose criteria soon with respect to the selection of new burial grounds and to improved operations at existing facilities.

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[10] See, 41 Fed. Reg. 43446 (October 1, 1976) announcing ERDA's intention to prepare such a document and Appendix I to the Notice setting forth an abbreviated outline of the proposed contents of that draft statement.

The Nuclear Regulatory Commission (NRC) as an agency and concurrently with the twenty-five Agreement States regulates the disposal of low-level and transuranic-contaminated waste. The NRC is endeavoring to develop a comprehensive regulatory program for waste solidification and terminal storage. Toward this end, that agency has recently prepared for eventual public comment a document entitled "Goals and Objectives for Nuclear Waste Management." The NRC does not intend to perform a programmatic environmental impact statement on its current waste management program, but plans to issue discrete statements on each waste management authorization. This NRC decision is being contested by the Natural Resources Defense Council in a rulemaking petition noticed by the NRC on September 16, 1976.[11/] The NRC is also preparing criteria and regulations on the acceptable form of solidified high-level waste and its packaging to be issued in final form in 1978. These criteria will result from work under contract being performed by the Lawrence Livermore Laboratory and the University of

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[11/] 41 Fed. Reg. 41759 (September 23, 1976).

Arizona. The NRC is also funding work by Sandia Laboratory on developing a methodology of assessing risks from geological isolation of high-level and transuranic wastes. The NRC has contracted for a classification study of radioactive wastes in response to a request from the Advisory Committee on Reactor Safeguards.[12] The NRC also reputedly has under review the twin issues of whether it should relinquish regulatory control over transuranic-contaminated wastes, if it requires ultimate disposal at an ERDA site, and whether it should resume regulatory jurisdiction over state-licensee commercial burial sites or take over ownership and/or operation of these sites. Also pending, as a result of the NRDC petition, is a decision on the continuation of commercial burial of transuranic-contaminated low-level wastes generated by nuclear reactors.[13] The NRC administers the State Agreement Program under Section 274 of the Atomic Energy Act of 1954, as amended, which is discussed in greater detail later in this paper. Together with ERDA, the Environmental

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[12] Letter from Dade W. Moeller, Chairman, Advisory Committee on Reactor Safeguards, dated April 15, 1976 to Marcus H. Rowden, Acting Chairman, Nuclear Regulatory Commission.

[13] See footnote 22, p. 18, *infra*, p. 5, n. 8.

Protection Agency, the Council on Environmental Quality and the National Science Foundation, the NRC has been active in conferences relating to radioactive waste management and is working on a federal interagency task force, chaired by the Office of Management and Budget, in an effort to coordinate all federal environmental impact statements and federal research and development projects relating to radioactive waste management.

The principal task of the Environmental Protection Agency (EPA) is the promulgation of radiation protection standards. Under Reorganization Plan #3, EPA had transferred to it not only the Federal Radiation Council's broad guidance responsibilities with regard to radioactive standards, but also the Atomic Energy Commission's function to establish environmental standards for the protection of the general environment from radioactive material. These standards will be used by federal and state regulatory agencies in determining the requirements for licensing and regulation of nuclear energy facilities, including those involved in the management of radioactive waste. In addition, pursuant to the requirements of the National Environmental Policy Act of 1969, EPA reviews and comments upon individual and programmatic environmental impact statements for nuclear facilities and advises states on the public health aspects of radioactive materials under the Public Health Service Act of 1970, as amended. The Marine Protection, Research, and Sanctuaries Act of 1972, as amended, the Safe Drinking Water Act of 1974, and the Federal Water Pollution Control Act of 1972 all grant EPA additional umbrance over radioactive materials.[14] EPA will be the permitting authority for ocean disposal of radioactive wastes, should this occur. As a result of its broad standard-setting authority and its NEPA activities, EPA has a significant impact on the nuclear waste disposal industry even though it lacks specific regulatory jurisdiction over all but ocean disposal of those materials.

The U.S. Geological Survey (USGS) advises and assists the NRC in assessing the geologic and hydrologic attributes of specific waste storage sites. This involves the actual surveying of sites such as those operated by Nuclear Engineering Company in Sheffield, Illinois, and Nuclear Fuel Services, Inc. in West Valley, New York. USGS is also participating in a cooperative program with the NRC for the development of regulatory criteria pertaining to these physical parameters. If the increasingly active role of the USGS in the licensing of nuclear power plants can be taken as a predictive model, one can expect that [illegible] agency, if left unchecked, will soon be exercising a standard-setting and quasi-regulatory role all its own with respect to radioactive waste disposal facilities.

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[14] But *cf.*, Train v. Colorado Public Interest Research Group, No. 74-1270, 96 S. Ct. 1938 (1976).

Regulation of radwaste disposal does not just occur at the federal level. Under Section 274 of the Atomic Energy Act of 1954, as amended, individual states[15] may assume regulatory and licensing jurisdiction over byproduct, source, and special nuclear material in quantities not sufficient to form a critical mass. As of December 1978, the NRC had concluded agreements for cooperation with 25 states.[16] Five of these states (Nevada, Kentucky, New York, South Carolina and Washington) license the burial of low-level wastes at commercial burial sites.

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[15] Local governments also impact upon waste disposal facilities through zoning and other permitting powers.

[16] Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Indiana, Kansas, Kentucky, Louisiana, Maryland, Mississippi, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, Oregon, South Carolina, Tennessee, Texas and Washington. 1 CCH Nuclear Regulation Reporter, ¶19,001.

With the exception of Washington and with the addition of Illinois, all of the commercial burial sites are located on state-owned land. The NRC and EPA, among other federal agencies, supervise state-licensed commercial facilities.

The federal government, regretably, has not promulgated a uniform set of criteria with respect to the specific contents of these agreements. In 1961, the Atomic Energy Commission approved criteria under which states may assume regulatory control over radioactive materials consistent with the compatability requirement of Section 274d(2) of the Act. These criteria are broad, woefully out of date, and offer the states no guidance as to the specific elements of a state regulatory program.[17] The Atomic Energy Commission together with the U.S. Public Health Service and the Conference of Radiation Control Program Directors in cooperation with the Council of State Governments, proposed such criteria in 1974, but they were never formally adopted.[18] The result is a tremendous variety in state requirements with respect to the facilities under discussion here.

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[17] See 1 CCH Nuclear Regulation Reporter, ¶19,201.

[18] Ibid, ¶19,201.

Concurrent regulation of low-level radioactive disposal by two levels of government, compounded by lack of uniformity at the state level creates obvious procedural problems for the waste disposal industry. There is a disparity in regulatory requirements among the several states as well as between the federal government and the states. The variation in regulatory requirements also means variation in the consideration of health and safety as well as environmental matters with respect to waste disposal facilities, variations in practice having little or no relationship to any present or past health or safety problems. There is no assurance, other than the emphemeral requirement that a given state's regulatory program be "compatible with"19/ the federal regulatory program, that these prodecural matters are being adequately addressed let alone regulated by the various states or even, as is frequently the case, that the various jurisdictions agree on the technological solutions being proffered. One must also question the ability of the several states to administer the regulatory effort required here, because of their more limited financial resources and technical expertise.

19/ Section 274d of the Atomic Energy Act of 1954, as amended.

Regardless of whether a state has regulatory jurisdiction under Section 274, state and local governments, responsive to the concern and pressures of their constituents, have been attempting to exercise what they consider to be their inherent police powers over the question of whether and how radioactive wastes will ultimately be disposed of. Kansas vetoed the selection of Lyons as a proposed salt-bed burial ground for high-level radioactive wastes. Governor Milliken of Michigan recently demanded assurance from the federal government that Michigan be able to veto any site within the State's borders selected by ERDA for a similar experiment. Connecticut passed a law this June (Conn. Public Act No. 76-321) regulating the transportation of radioactive material shipped from or through the state to a waste disposal site or facility. New York City promulgated amendments to Section 175.111 of the New York City health code in effect prohibiting the transportation of radioactive materials within the city limits. Suffolk County, New York is considering similar legislation as is Cincinati, Ohio, and New York is debating whether to include radioactive materials in the state's more stringent regulations governing hazardous materials. Massachusetts is considering legislation to monitor nuclear installations

(MASS 1085 "Monitoring of Nuclear Institutions") and Kentucky has enacted a $.10 per pound excise tax on the receipt and burial of all radioactive materials and containers (KRS 138.810-860). This latter instance of state activity alone has reduced the monthly quantity of materials received at Nuclear Engineering Company's Maxey Flats waste disposal facility from 78 thousand cubic feet to 3 thousand cubic feet. This tax, by imposing what amounts to a 500% increase in burial costs has not only resulted in a severe loss of revenue for the owner of the facility and has virtually closed the site as a disposal source for its customers, but paradoxically has also resulted in a loss of revenue for the state, as these wastes are now being shipped to other locales. Whether this or any of the other attempts of state and local governments to enter the field is consistent with the Atomic Energy Act or the Commerce Clause of the Constitution may be left to another day. One can be assured, however, that other such instances will occur should there develop at the federal level a movement to increase state control over nuclear waste management.[20]

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[20] See for example, HR 15673 (September 23, 1976), not yet enacted, which proposes giving states a veto over ERDA waste disposal facilities.

It should be evident from the foregoing discussion that the federal-state interface in the radioactive waste disposal area is dysfunctioning. This in turn has spawned a host of problems for the industry and regulators alike, such as, lack of systematic site selection criteria for future disposal sites and of uniform standards for determining regulatory issues, a lack of timely and effective licensing by state and federal regulators, the failure of either the federal or state governments to establish perpetual care and maintenance provisions for commercial disposal sites and to assure the adequacy of additional funding provisions to meet such requirements. The NRC has not in fact determined in two years the type of radioactive wastes that can be safely disposed of by shallow burial[22] with the result that South Carolina, New York and Kentucky have seized the regulatory initiative and prohibited the commercial burial of transuranic-contaminated wastes.

There is a clear statement in regulation in this area and this statement, perhaps as much as anything else, is responsible for the lack of public trust in the decisionmaking process as it affects the nuclear industry.

Perhaps one reason that institutional solutions to this statement have not been forthcoming is that the problems involved in a program calling for shared federal-state regulation are tremendously difficult to solve. Radioactive waste disposal presents an area of regulation which requires on the one hand the resources, expertise and uniformity of federal regulation, but on the other hand intimately affects the concerns of state and local governments. Therefore, one is presented with a problem requiring accommodation of these interests. Further, any institutional solution will impact upon existing bureaucracies and in all likelihood, as proposed in this paper, call for a reduction in the scope and power of some of these organizations. Needless to say, making such a proposal, let alone implementing it, will not be politically popular. Further, a specific problem involved here is that the regulatory solutions fashioned today will affect a substance which will far outlive their passing. This raises institutional challenges, such as creating a regulatory system which can be self-perpetuating and independent of the nuclear industry as we know it today or even existing social or governmental institutions as all of these may change. What is called for clearly is bold, decisive leadership.

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[22] In 1974 the AEC proposed to ban shallow land burial of all transuranic-contaminated waste and issued a supporting draft environmental statement (WASH 1539). The statement was withdrawn by the Commission and the rule has remained in limbo ever since. 39 Fed. Reg. 32921 (1974). Recently, ERDA announced the preparation of a generic programmatic environmental impact statement concerning the management of commercially-generated radioactive wastes, which is to replace WASH 1539. 41 Fed. Reg. 43446 (October 1, 1976).

Finding an institutional solution, therefore requires first and foremost a realistic evaluation and accommodation of the interests and abilities of the governmental jurisdictions currently competing for control for these facilities. This evaluation must be conducted vertically (i.e., federal-state) as well as horizontally (i.e., NRC, ERDA, EPA). In my opinion, any such evaluation could occasion the following suggestions: (1) a reassertion of extensive federal licensing jurisdiction over the management of low-level radioactive wastes; (2) a concomitant reduction in state administrative responsibilities with respect to these wastes and an institutionalization of meaningful state participation in certain defined areas of decisionmaking; (3) the appointment of the Nuclear Regulatory Commission as lead agency in the regulation of these wastes, including the sole authority to promulgate standards with respect to the method of disposal and maintenance of these wastes as well as procedures for constructing, operating, safeguarding and caring for these facilities; and (4) the possible utilization of a neutral body of experts to advise on the selection of geographic areas for the location of these facilities and even perhaps to advise on funding for their perpetual care and maintenance.

It seems clear from the complexity and hazardous nature of the subject being regulated and the concomitant demand for financial and technical resources to deal successfully with the problem, that only the federal government can provide a system of uniform and effective regulation. The scope of public concern attendant to the disposal of these wastes is no less intense than that involved in the construction and operation of utilization and production facilities, which are currently regulated, in their radiological aspects, exclusively by the federal government. Further, low-level wastes pose many of the same problems with respect to their disposal, although of a lesser order of severity, as high-level wastes, which have always been regulated at the federal level.

Although under this proposal, states will lose much of their direct authority to license and regulate low-level waste disposal facilities, I propose to compensate for this loss by institutionalizing, and thus, assuring, state participation in certain decisions to be made at the federal level. Since whatever solution is eventually adopted for the geographic distribution of these wastes will occasion locally perceived inequities, it becomes doubly important to assure maximum state participation in the full range of decisions affecting the specific location of the facility within a given state's borders as well as the evaluation of the environmental and health and safety aspects of the facility's construction, operation and future maintenance. Procedures will have to be designed to accommodate this participation. These could vary from state comments on specific federal licensing activities to joint hearing boards composed of representatives from both levels of government at which these issues and any other issues of specific concern to the state could be ventilated. The states should be encouraged to participate through the comment mechanism in the development of site-specific monitoring and surveillance requirements for these facilities to be implemented at the federal level. The Council of State Governments could be effective in this regard. States might even contribute inspection teams to work along with their federal equivalents to ensure proper enforcement of federal regulations.

Maximum state participation in waste management matters will of necessity involve a number of state agencies. Not only should there be a consultation with state public health agencies but also the role of the state public service commissions in waste matters generally has to be taken into account. At this time, there is very little guidance available to state public service commissions as to the economic and technical considerations involved in the treatment of waste for purposes of utility ratemaking. As the nation's nuclear program develops, the state public service commissions will have to make important decisions affecting consumer interests in terms of their electric bills. If the Kentucky burial site should be closed because of the state excise tax, then the additional transportation costs for burying the wastes elsewhere will be borne by the electric consumers. Guidance as to the cost to utilities of handling nuclear waste must be part of any comprehensive federal regulatory program. Disparity in the treatment of utility waste management costs by the state public service commissions can only result in a variation in the ultimate cost to consumers of the power produced from nuclear generating plants.

At the federal level, there is a clear need for one agency to step forward and exercise the full decisionmaking burden of regulation of nuclear waste management. It seems equally clear at the present that that agency should be the NRC because of its historical expertise with respect to the regulated material. The NRC has both the enabling authority and machinery to adopt the necessary standards and regulations to govern the disposal of all types of nuclear wastes. ERDA should retain its R & D function in this area consistent with the philosophy behind the dismantling of the AEC.

There are two discrete issues involved in nuclear waste management which severely test the capacity of the existing bureaucratic structure in terms of both its public credibility and objectivity. These issues are the geographic location of waste disposal facilities and the funding of their perpetual care and maintenance. The highly political nature of these issues is a matter of much concern. One method of achieving important and early decisions on these subjects with a greater potential for public acceptability would be the creation of a neutral body of experts. This body could be composed of individuals drawn from both public and private life either in the form of a new federal advisory body or a quasi-governmental corporation[11] or perhaps as a separate function of the existing Advisory Committee on Reactor Safeguards. If a quasi-governmental corporation were selected to perform these functions, it could of course be empowered to issue bonds to finance its activities as well as to fund the perpetual care and maintenance of waste disposal facilities. If it had this power, the corporation would require revenue generating authority as well. Both the power to issue bonds and to produce revenue would make the corporation independent of the political mainstream in these two important respects. Regardless of whether a new political body were created or a new function engrafted upon an existing institution, it is suggested that the organization have both rulemaking and adjudicatory powers to assure full public ventilation of its decisions. Their decisions should be subject to judicial review only, thus further assuring independent action.

The solutions I have suggested are as much a matter of political philosophy as of anything else. Basically they call for a continuation of our federal system of government in this area and depend upon a smooth interfacing of competing jurisdictions within more clearly defined and circumscribed areas of authority. The immediate burden of the solution falls upon the NRC. It must act now to reassert its licensing jurisdiction over radwaste disposal as well as grasp the administrative initiative in proposing standards and drafting regulations to govern effectively this most challenging problem. This does mean precipitous action but rather thoughtful effective resolution.

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[11] Mason Willrich in his Draft Radioactive Waste Management and Regulation Report to ERDA proposes the creation of national radioactive waste authority to own all waste disposal facilities in which transuranic-contaminated and high-level wastes are buried. This solution appears extreme to me in that it calls for the take-over of all such facilities by the government be they commercial or government-owned.

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SOCIAL AND ETHICAL ISSUES IN THE IMPLEMENTATION
OF RADIOACTIVE WASTE MANAGEMENT OBJECTIVES

by Dean E. Abrahamson[1]

NATURE OF RADIOACTIVE WASTES FROM ATOMIC POWER REACTORS

Atomic power reactors produce radioactive by-products and these products are regarded as waste:

- The operation of a nuclear fission reactor results in the creation of radioactive products.
- Although not identical, the nature of the radioactive products is qualitatively and quantitatively similar regardless of reactor type.
- There is *not* now any commercial use being made of the bulk of these products. Hence, these products are waste.
- As waste, their management is a "nonproductive" activity for the firms involved with their production. As with other pollution control, the money spent to build or operate waste control systems does *not* increase the desired output of the enterprise, in this case electricity.
- These wastes are modest in volume and mass but are highly radioactive, can be taken up in food chains, and are persistent.
- Various waste management schemes have been under discussion for decades. These schemes fall into four broad categories: (1) "treat" them to render them less toxic or less long-lasting, (2) remove them from the earth through some sort of rocket scheme, (3) sequester them on the earth in either retrievable or irretrievable form, and (4) make them elements of commerce.

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[1] For presentation at Conference on Public Policy Issues in Nuclear Waste Management, sponsored by the Energy Research and Development Administration, the Nuclear Regulatory Commission, the National Science Foundation, the Environmental Protection Agency, and the Council on Environmental Quality, Chicago, Illinois, October 27-29, 1976. Dean Abrahamson is Professor of Public Affairs, University of Minnesota, Minneapolis, Minnesota, 55455. The help of George Woodwell, Tom Bauer, John Brandl, Donald Geesaman, and Herman Daly in reviewing and commenting on drafts of this paper is gratefully acknowledged.

- The technical details associated with these schemes are influenced by reactor type, method of processing the spent reactor fuel, and other considerations - none of which have yet been clarified.

Consider the ton or so of fission wastes produced during a year of operation by a 1,000 megawatt (electrical) nuclear power plant. Of this total inventory, ignore all but one fission product isotope, cesium-137. It is sufficiently unpleasant that if all the other fission products appeared as common ash, cesium-137 would itself constitute a major problem of radioactive waste. About 60 pounds, or 3 percent, of the reactor's yearly fission products appear as this waste material. As reference values, the official guidance for a maximum permissible body burden is about one trillionth of that amount, and local surface contamination of one thousandth of that amount per square mile would give an ambient exposure to ionizing radiation of about 1,000 times the usual natural background of exposure. The half-life for this isotope is 30 years, and hence over a social time interval, such as a generation, the radiological activity of cesium-137 wastes would diminish by only a half.

The 60 pounds of cesium-137 produced by operating a nuclear power plant for a year have the potential of excluding humans for hundreds of square miles for decades. It is projected that the accumulated activities of cesium-137 in the United States during the 1980s will represent thousands of reactor-years of operation. Fuel reprocessing plants, such as the one under construction at Barnwell, South Carolina, might have in localized surface storage the inventory produced by 50 such reactors during 10 years of operation, that is, almost 500 times the annual contribution of one typical reactor.

Cesium-137 illustrates the significant social problems associated with fission wastes; the amounts are physically small, the times involved may be politically long, and the potential for damage is very large. Cesium-137 is only one of the bothersome fission wastes.

The radiological problems of the fission fuels are similarly grave. Neutrons produced in the fissioning of uranium-235, the only naturally occurring fission fuel, are used to breed new fission fuels, of which plutonium-239 is representative. The bred fuels are the dominant nuclear fuels in the projected breeder reactor economy of the future, and they have been considered (until recently?) a vital part of the fuel cycle economics of the present generation of reactors. These bred fuels have two prejudicial characteristics: they are radiologically thousands of times more toxic than uranium-235 (whose chemical and radiological toxicity levels are similar); and they are suitable materials for the construction of nuclear explosives.

A 1,000 megawatt (electrical) light water reactor can produce 400 to 600 pounds of plutonium yearly, potentially worth several million dollars and having a total volume of about a cubic foot. That the official guidance for a maximum permissible lung burden of plutonium is a hundred trillionth of this amount, and that the air concentration standard for plutonium is one part per million billion is a commentary on its acknowledged potential for injury. Plutonium-239 has a radiological half-life of 24,000 years, so unless it is consumed as fuel it will persist for geological times. Plutonium-239 is only one of the transuranic elements found admixed with other fission wastes.

Consider further the potential spatial and temporal extent of the contamination which could result were waste storage to fail. A surface contamination could, in principle, be cleaned up. Spills of fission products have been cleaned up. Plutonium spills have been cleaned up -- for example in Spain, in Greenland, and in Oklahoma.(1)

The failure of an underground waste repository could be disruptive. Individual aquifers may be between tens and thousands of miles in extent. Characteristic times for water retention in these aquifers may be from tens to thousands of years. Eventually any contamination would find its way into surface waters -- the quantitative relationships would depend on, among other things, the

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(1) In addition to the considerable economic cost associated with such decontaminations, there can be considerable disruption. The Oklahoma instance is illustrative and suggests the grave problems which would result were there an extensive contamination of, for example, an urban area: "...no more than 0.0003 grams of plutonium were identified in the contamination of the individuals and their apartment. . . Contamination was removed by repeated scrubbings where possible. Items considered not decontaminable or difficult to survey were removed . . . for treatment as contaminated waste. Furniture removed included the sofa, tables, television set, bedding, refrigerator, and range. Carpeting was removed, as were a few tiles from the bathroom. About twelve fifty-five gallon drums of smaller articles were removed. These materials were taken to the . . . facility pending final disposition." [illegible] Investigation Report No. 74-09, Directorate of Regulatory Operations, U.S.A.E.C., "An Employee and Her Residence were Found to be Contaminated with Plutonium," [illegible] issued early 1975, available from Chicago Operations [illegible] [illegible]

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solubility of the wastes, time constants associated with the hydrological properties of the aquifer in question, the half-lives and concentrations of isotopes in the waste, and the degree to which the aquifer served as a water source for surface activities.

Although some of the waste components of the nuclear fuel cycle are hazardous because of their chemical properties, these pale before the radiological hazards. The wastes, if released by design, through act of malice, or by accident result in direct radiation exposure to man and other living things and also result in such exposure through their entry into food chains. Man is the critical species. The degree of exposure is related to the quantity of waste which finds its way into the local environment.

It is accepted, for purposes of considering standards governing exposure to ionizing radiation, that the effects associated with exposures are: (1) cumulative, with doses received at different times being strictly additive; (2) proportional to dose in the low-dose regime; and (3) no-threshold phenomena with no dose below which there is no effect. The effects usually considered are: (1) death occurring relatively soon after exposure to high doses; (2) genetic damage; and (3) a variety of somatic effects, including the induction of cataracts, cancers and leukemias, and non-specific life-shortening.(1) Although the biological mechanisms relating radiation exposure to the subsequently observed clinical condition are not well understood, the dose/response relationships appear to be becoming well enough known on the basis of various radiation exposure situations, experimental and other, for public policy purposes. It is sufficient to note that the levels of radiation exposure to the public resulting from the nuclear fuel cycle is known(2) to be causing an increase in the incidence of cancers, of leukemias, and of genetic damage although these increases are frequently not demonstrable,(3) and that the public widely regards radiation releases as posing considerable hazard (and curiously, the hazard of radiation from medical uses seems to be regarded differently from those from other commercial activities). A breach in radioactive waste management discipline could result in major public health and property damage.

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(1) There is at least one behavioral effect as well, although it is usually not explored in the scientific literature. It is the "radiation effects and standards discussion syndrome", easily noted by observing the participants during the often spirited discussions of radiation standards.

(2) See, for example, Thomas F. Mancuso, Alice Stewart, and George Kneale, "Radiation Exposures of Hanford Workers Dying from Various Causes", to be published (presented at Tenth Midyear Symposium of the Health Physics Society, Saratoga Springs, New York, October 11-13, 1976).

(3) For an interesting exchange see letters from Bertram Wolfe and Frank von Hippel, Science, 29 October 1976, pp. 478-480.

MANAGEMENT STRATEGIES

As mentioned above, there are two more or less distinct components of the radioactive waste: fission products, the most troublesome of which have radiological half-lives in the neighborhood of 30 years, and the transuranic isotopes formed through neutron absorption by the uranium or thorium used as fuel. Many of these heavy isotopes have radiological half-lives of thousands of years.

Two methods of "treatment" have been proposed: chemical separation of the wastes to isolate the relatively short-lived from the very long-lived isotopes, and "burning" at least the long-lived isotopes, and perhaps all of the wastes, by exposing them to neutrons having an appropriate energy. The products of this "burning" would be new fission products and other radioactive activation products. The result could be a reduction of the effective half-life of the wastes such that storage times of about 1000 years can be considered instead of the hundreds of thousands of years which would be necessary for either the long-lived component or fission products mixed with the long-lived transuranic isotopes.[1] Although theoretically feasible, there is no means now available, nor is there any reasonable prospect of means being available, for the "treatment" of these radioactive wastes to render them less radioactive or less persistent. There are means known to put them into relatively insoluble form and hence less apt to enter the biosphere.

Schemes to sequester the wastes on earth fall into two classes:[2] those in which the wastes would be retrievable at some later date, and those in which the wastes would not be retrievable. A mausoleum or storage vault would provide

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[1] These treatment options are described in many places. For a particularly concise description see, e.g., A.S. Kubo and D.J. Rose, "Disposal of Nuclear Wastes", Science, December 21, 1973, pp. 1205-1211.

[2] An enlightening view of waste management is found in "Minutes of the Meeting of the Advisory Group on Contributions of Technology to Economic Strength," April 27, 1976, Dr. Simon Ramo, Chairman. Copies available from the White House, Washington, D.C.

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the option of retrieving the wastes at a later time, and in fact would necessitate retrieval if only as a result of deterioration of the mausoleum. The various salt mine, "permanent" ice, or other deep subsurface schemes would not retain the option of retrieving the wastes.

Various proposals have been made to shoot the wastes -- or at least the long-lasting components of the wastes -- into the sun or somewhere else in space. These proposals have often occurred at times when the space program in general was under discussion, for example during periods of debate over the continued funding of the space shuttle program.

There have been a number of suggestions that the wastes be "mined" to recover those components which have, or might have, commercial application.(1) I am not aware of any serious suggestions that all, or even the major part, of the wastes have commercial value, but there are an increasing number of products proposed, under development, or already available which would incorporate components of the radioactive wastes. These include americium smoke detectors, plutonium powered cardiac pacemakers, neptunium powered watches, tritium landing lights, plutonium heated diving suits, plutonium powered artificial hearts, cobalt spark gap irradiators, promethium photo-identification cards, and a number of other devices.

TECHNICAL STATUS OF THE WASTE MANAGEMENT OPTIONS

Substantial resources have been allocated to achieving a technical resolution of the problems of nuclear waste management. During the past few decades large number of reports have been written.

Substantial quantities of these wastes have already been produced both by military programs and the civilian nuclear power industry. As Mason Willrich(2) has summarized, there is no satisfactory program for the management of these wastes. At present the military wastes, and a small fraction of the commercially generated wastes, are stored in temporary tanks. The bulk of the civilian wastes are yet contained in the spent reactor fuel, most of which is being kept at individual power reactor sites.

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(1) A further list, and discussion, of these commercial uses of nuclear wastes is found in the appendices to the April 22, 1976, meeting of the Ramo committee cited at footnote 5, page 8, *supra*.

(2) M. Willrich, "Radioactive Waste Management and Regulation", session IV, this conference.

There is little indication of willingness to assume the costs of chemical separation. There seems virtually no prospect of the several neutron irradiation schemes being feasible for at least many decades. There is no long-term storage site either of the retrievable or the irretrievable varieties. There is, insofar as I have been able to determine, little enthusiasm for the option of shooting the wastes into space.

All wastes currently being stored, and all wastes which would result from processing or reprocessing contemplated for the near future, contain both long-lived transuranic isotopes and fission products. We must assume, for purposes of current policy discussions, that society can be protected only if the wastes are isolated in perpetuity -- or at least for times that are very long compared with the relevant social times. And, we have no policies thought of in these terms. The more common policy premise is incrementalism -- questionably suitable for this problem.

It is interesting that there seems to be the most progress in the option of finding commercial application for components of the radioactive wastes. A number of products are already on the market, or are in use in military or space programs, and others are said to be in the near-commercial stages of research and development.

RADIOACTIVE WASTES ARE NOT THE ONLY PROBLEM

The public debate over the acceptability of nuclear fission as a commercial energy source was initially driven by a set of concerns associated with the presence of radioactive waste materials in the nuclear fuel cycle. Were it not for the radioactive wastes there would be little concern regarding releases from power plants, reprocessing plants and the like; there would be somewhat less hazard were there to be a reactor core melt-down; and of course there would not be the range of issues which prompted this conference.

The presence of special nuclear materials at several points of the nuclear fuel cycle gives rise to another set of problems. There is a considerable overlap of potential for the use of the nuclear fuels for the production of commercial energy and the production of explosives. The plutonium and other potentially useful isotopes must be considered as wastes pending the acceptance of proposals to make them elements of commerce.

In addition to these intrinsic physical characteristics of atomic power there are a number of important questions of economics, of patterns of ownership, of institutional arrangements, of capital formation and the implications of large stocks of capital. It is not uninteresting that a clash between growth economics and the notion of free enterprise seems to be evolving in the context of nuclear power, and that by its very nature nuclear technology must involve more centralization of control.

All of these issues, as well as others, are a part of the policy debate over the acceptability of nuclear power. Waste management is but one of the issues.

THE TECHNICAL CONSTRAINTS

A general statement of the constraints -- from a radiological standpoint -- on the nuclear power industry is included in the summary of the 1972 BEIR[1] report:

> Concern about the nuclear power industry arises because of its potential magnitude and widespread distribution. Based on experience to date and present engineering judgment, the contribution to radiation exposure averaged over the U.S. population from the developing nuclear power industry can remain less than about 1 mrem per year (about 1% of natural background) and the exposure of any individual kept to a small fraction of background provided that there is: (a) attainment and long-term maintenance of anticipated engineering performance, (b) adequate management of radioactive wastes, (c) control of sabotage and diversion of fissionable material, (d) avoidance of catastrophic accidents. (emphasis added).

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(1) "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation", Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, November 1972, page 1.

There are various summaries of the technical constraints on attainment of "adequate management of radioactive wastes". Typical of them is that of J. Hamstra:[1]

> The conclusions to be drawn from this review are that (1) there are no long-term radiotoxic hazards as a result of the disposal of high-level reprocessing wastes in a deep geological formation in excess of other known and accepted radiotoxic hazards; (2) _provided_ the burial areas are so arranged and situated that the high-level reprocessing waste is kept out of the hydrologic cycle for at least 300 to 500 years [see note (2) below], the disposal of high-level reprocessing wastes is a solvable problem, mainly to be concentrated on the site selection for and the design of the burial facility; and (3) _if_ such a disposal area is found, this area can also be used as a dumping cavity for the low- and medium-level wastes since their radiotoxic hazards are far smaller. (emphasis added).

When translated, those statements, and others like them, say that nuclear power is safe _if_ there are no failures of the associated technical or social systems. And, the radioactive wastes will not cause problems _if_ they do not find their way into the biosphere.

The imperative is clear, and well recognized. The radioactive wastes must be totally contained and their isolation permanently guaranteed. This is a long way from the standby axiom of "dilute and disperse" which governed our conventional waste management strategies for so long.

WHO SHALL DECIDE, AND WITH WHAT INFORMATION

A central issue in the nuclear power debate is who shall decide. The question applies not only to the broad issue of the acceptability of nuclear power but also to the various considerations of economics, of waste management, of safeguards. The decision about adequacy of radioactive waste management and about acceptability of nuclear power -- which hinges in part on the perception of adequacy of the waste management objectives and means proposed to meet those objectives -- will be made by the public acting through the established political process. The technical community has the right and obligation to responsibly address the issue of waste management and propose the means. But the decision on adequacy is political.

The importance of the adequacy of waste management is widely recognized. For example, many (if not all, I've not checked them all) of the citizens' initiatives on nuclear power include consideration of waste management. The initiatives include a requirement like "it be established that there is no reasonable chance of radioactive wastes escaping to the environment through imperfect technology, acts of God, sabotage or other causes."

I know of no example of the public being asked to make a decision on the adequacy of a nuclear waste management option and it is unlikely that such will ever be the case. Rather, the public has, and will, express itself on the broader question of nuclear power. To date, the nearest to an uncluttered(1) test of the political acceptability of nuclear power has been in the recent Swedish elections. The party in power prior to the elections advocated major expansion of the nuclear option. The principal opposition party urged the total abandonment of nuclear power. As it developed, the nuclear issues was (according to the Swedish press and the involved politicians) the decisive issue. Whether or not the promises and claims made during the heat of that campaign can be kept remains to be seen, but the people participated through the ballot box. We may surmise that they, were guided by their personal evaluation of the social, ethical and moral implications of nuclear power. It is unlikely that many of them were able to, or were particularly interested in, making a "technical" evaluation of either nuclear waste disposal programs or the other issues. Their notions of the technical situation were probably based on what they were told by individuals they had reason to trust -- individuals who themselves, or as spokespeople for institutions or agencies, had a reputation for being reasonably accurate and above all being candid about similar or related issues in the past.

Representatives of the nuclear industry, and the experts in nuclear technology are probably distressed that their assurances about the ease of managing nuclear wastes, and about other things nuclear, are not accepted by a sizable fraction of the voting public. In his discussion of the ethics of energy development Dr. Robert Seamans, Administrator of the Energy Research and Development Administration, said:(1)

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(1) By "uncluttered" I mean that the issue was cleanly drawn as whether or not to abandon the fission option -- there was no monkey business with halfway proposals. I certainly do not mean to imply that the nuclear issue was the only thing involved in the choice between parties for such was far from the case.

> Many [who are] fearful of future radioactive disaster seem to lack confidence in two things: the moral sensitivities of the scientists and engineers who are producing the technologies and the technologies themselves.

Implicit in Dr. Seaman's comment is the notion that the scientists and engineers are themselves resolving non-technical issues. How else could their "moral sensitivities" even be an issue? Or does competent science and competent engineering depend on the practitioner being morally sensitive? Is it possible that science itself is not value-free? As to the adequacy of the technology itself, the record is clear that Dr. Seamans is correct; there is a lack of confidence. But the public, and many of the leading nuclear critics upon whose work such public concern rests, are neither interested in nor able to make their own evaluation of the adequacy of each of the technologies. Why is there a lack of confidence in the interpretations offered by the nuclear establishment? Consider as an example a recent comment by Representative Mike McCormack:(2)

> "Long before 1983 -- as a matter of fact, within the next 24 or 36 months, at the very most -- we are going to have all of the environmental impact statements written and all of the technology completed on waste disposal, on the fuel cycle, and on the questions that have been in controversy during recent months. The technology is 99 percent complete in these areas.

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(1) R.C. Seamans, Jr., "Ethics of Energy Development", Associated Church Press and Catholic Press Association, Washington, D.C., May 6, 1976. There have recently been a number of attempts to address social, ethical and/or moral considerations in evaluating energy options. Perhaps the most satisfactory of such evaluations (in this case of a medical technology rather than an energy technology -- but there are many similarities) is reported in, A Report by the Artificial Heart Assessment Panel, National Heart and Lung Institute, "The Totally Implantable Artificial Heart: Economic, Ethical, Legal, Medical, Psychiatric, Social Implications," DHEW Pub. (NIH) 74-191, June 1973.

(2) Congressional Record, June 30, 1975, p. H6683.

> What is holding us up now is the final drafts of the necessary environmental impact statements." (emphasis added).

The ongoing nuclear studies, the research and development, and the necessity for this very conference stand as testimony to the variance between the actual situation and Mr. McCormack's representation. Yet, he characterizes himself not only as a Member of Congress with particular interest in energy matters, but also as being expert in nuclear technology.

Public statements about other aspects of nuclear power also influence the credibility afforded spokesmen who attempt evaluations of the adequacy of nuclear technology. What is claimed for the techniques of waste management will be judged, to a certain extent, in the context of the record of other claims. In the light of subsequent developments, how is the credibility of the nuclear industry as a whole affected by a statement such as that of J.W. Simpson, then in 1973 president of Westinghouse Power Systems and as such the company's top nuclear officer:[1]

> We have firm uranium commitments that match our requirements throughout the term of all of our contracts.

That many members of the public consider the problems posed by nuclear wastes to be major, and that there is a lack of confidence in the nuclear industry's ability to satisfactorily deal with them or to accurately represent them should not be surprising. I for one am upset by misleading statements made by individuals on both sides of the nuclear debate, but particularly so by those who, by virtue of their holding a position of responsibility, are expected to be subject to a high level of accountability. To simply restore confidence in the institutions responsible for nuclear wastes is a social concern which must be given high priority. Also, is there not a point at which ethical issues are involved by overly optimistic (or pessimistic for that matter) public announcements about how things are going?

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[1] Comment to a meeting of security analysists in Florida, as quoted in The Wall Street Journal, September 30, 1975, pp. 1 and 20.

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I believe that it has been decided that the adequacy of nuclear waste management objectives will be judged by the electorate as part of the broader question of the acceptability of nuclear power. But we continue to see attempts to internalize the decisions on nuclear power, including waste management, to those who are accustomed to dealing with the technical aspects of the issues. If nuclear power decisions are political, then the perception of the adequacy of the process, and as to the adequacy of current and past industry practice, is important. In many instances the perception of an issue's significance -- from a technical standpoint -- or of the status of a management strategy -- whether or not this perception is significantly at variance with what the "experts" know to be so -- will be the deciding factor. Perhaps some genuine public education and opportunity for meaningful public participation should have been included in plans for implementing radioactive waste management proposals.

That there is no agreement that the determination of the adequacy of the safety of nuclear power and of waste management strategies properly are political issues is itself evidence of a failure of process.

THE OPTION OF NOT PRODUCING MORE RADIOACTIVE WASTES

Although this conference is predicated on the assumption that there will be additional nuclear wastes produced, I think that we should, at least briefly, consider the option of not producing any more. To not produce more wastes would satisfy any set of waste management objectives, although we still must cope with wastes already in hand. To evaluate this option requires examining the arguments advanced for and against continuing to maintain a relatively high growth rate in energy use, and examining the alternative supply options. If nuclear power is deemed necessary to meet more basic goals and to satisfy basic values, then we will have to adjust. If not, then we will have to adjust to something else. Either way, we must deal with the implications of a social philosophy which I believe is as widely followed today as when the following rather terse statement was featured in the guidebook of the 1933 Chicago World's Fair:(1)

> Science finds, industry applies, man conforms.

It is with the question of sustaining energy growth rates that many advocates for nuclear power begin their arguments. Do these arguments have social and ethical content? First, an industry spokesman:[1]

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(1) As quoted in R. Dubos, "The Despairing Optimist", American Scholar, Winter 1971/1972.

> Another factor that will create additional demands for power is the growth in our standard of living. In general, the living standard of any given family in the United States can roughly be measured by the number of appliances it has and by the amount of electricity it consumes, just as the total power consumption is a good indicator of the standard of living of a nation.

Mr. Simpson, of course, has a particular interest in appliances and electricity, but Congressmen do not:[2]

> Without an adequate clean supply of electrical energy: First, we cannot maintain our present level of consumer goods production; second, we cannot increase the quantity of consumer goods to supply the inevitable increase in population between today and the year 2000 A.D. Third, last but not least, we cannot produce the devices which will give us the deterrent military strength to prevent nuclear war, and establish by credible negotiation a universal peace...we must double our present generating capacity by 1980. We must double the 1980 generating capacity by 1990. We must increase the 1990 generating capacity by a minimum factor of 50 percent, or by a possible factor of 100 percent by the year 2000.

To be sure, the projections of increasing energy consumption have been tempered by the events of the past few years, but there has as yet been no effective change in the perception of the necessity for growth. A few weeks ago,

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[1] John W. Simpson, President, Westinghouse Power Systems Co., speech to the St. Louis, Missouri, Electrical Board of Trade, February 9, 1971, reprinted in the Congressional Record, March 1, 1971, pp. 11564-1565.

[2] Rep. Chet Holifield, Congressional Record, June 4, 1971, p. H4722.

Robert Seamans summarized his ethical arguments for continuing with the nuclear option:[1]

> We need new energy sources to maintain the security and policy independence of the nation; to maintain a strong and healthy economy and adequate employment; to permit individuals to choose their life styles without limitation because of energy shortages; to remove the temptations for dangerous international competitions over the dwindling energy supplies now used; and to provide energy sources that are more benign to the nation's environment. These are ethical goals and we seek to achieve them by ethical means...[then, after considering alternatives and finding them wanting]...That is why nuclear power plays such a central role in this scenario. We must increase our use of nuclear fission reactors much faster than the rate of increase today.

Mr. Seamans recognizes the ephemeral nature of oil and natural gas, and the associated geopolitical concerns. The root of his concern is with avoiding unnecessary disturbance -- in the very short run -- associated with these fuels and in assuring a sustained capacity to meet high growth rates in energy consumption. His analysis, as well as that of many others, seems to assume that: well being -- personal and national -- is proportional to economic activity; economic activity requires a value of energy use per dollar of gross national product which approximates historic trends; hence, well-being requires maintenance of high rates of energy consumption growth rates; and, finally, rapid expansion of the nuclear option is necessary to maintain those growth rates.

Whether or not these assumptions are valid -- and there is a growing body of evidence which suggests that they are not[2] -- their acceptance is clearly a function of the values of the beholder. And there is another value laden factor -- employment. Mr. Seamans, and others suggest that continued high growth rates in energy consumption are required to "maintain adequate employment". Of course, employment is provided during the construction and operation of energy supply facilities but there are fewer new jobs per dollar invested in the energy supply facilities than with virtually any other sector of our economy. As to employment implications of energy use it has always seemed strange that although a primary factor involved in increasing energy consumption is the replacement of one factor of production, labor, with another, energy, that yet somehow more energy use implies more employment.

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[1] R.C. Seamans, Jr., citation at footnote (1), page 11.

[2] Consider, for example, the recent report of the Royal Commission on Environmental Protection in the United Kingdom. Sir Brian Flowers, Rector of Imperial College and Chairman of the Commission concluded: "We acknowledge here the possibility that there may indeed be no practicable alternative [to the nuclear option], but we have not been convinced by the evidence that this is the case...." as quoted in Not Man Apart, October 1976.

There seem to be at least three ways to "maintain adequate employment". Continue the present patterns with high levels of "structured unemployment". Restore growth patterns of the recent past with higher employment, and an ever increasing throughput of all natural resources, including energy. Or, move toward an economy less dependent on the flow of raw materials and more appreciative of the stock of goods, less prone toward "structured unemployment" and more sensitive to providing jobs for all -- whether or not they have the technical skills for, or predilection toward, "modern" production methods.

Clearly one's perceptions of individual worth, of the nature of work, of the place of each individual in the scheme of things, will heavily influence one's consideration of these matters. One can only conclude that when Mr. Seamans, and others, suggest that continued high growth rates in energy consumption are required to "maintain adequate employment" that they are making value judgements.

One cannot proceed very far along these lines without asking about the non-industrialized peoples and the impact of our energy decisions on them. No matter how we approach the question, it seems that the evolution of a "higher quality of life" in the developing nations would be associated with a higher energy consumption. I do not suggest that lack of access to "adequate" energy has been a significant factor impeding development nor do I suggest that "higher quality of life" necessitates a development strategy which is in concert with those of the industrialized, energy intensive, economies such as that of the United States. What I do suggest is that the interests of the peoples of the non-industrialized nations must be considered in our evaluations of energy policy options and that this evaluation must begin by reviewing our assumptions and practices influencing growth, our use of natural resources, and equity.

The second part of evaluating the necessity of producing the nuclear wastes is that of alternative energy sources. Are there viable alternatives to nuclear fission? Again, the answer depends upon the determination as to "necessary" growth rates in energy consumption. If the satisfaction of human values is consistent with lower levels of per capita energy use than those which would result from continuation of historic growth trends -- that is, a leveling of energy consumption with reduction in the per capita use by the peoples of the industrialized nations so that the peoples of the developing nations can have more available to them -- then energy requirements can be supplied from natural energy flows, primarily solar energy. If such is not the case, then the stock of fossil fuels, primarily coal, could, at considerable environmental and social cost, sustain the burden of energy production (in the absence of nuclear power) for several decades, but not in the long run. The only known alternative to nuclear fission, assuming the necessity for very high levels of consumption, is nuclear fusion. Given the history and current status of fusion research and development it would be highly imprudent -- if not irresponsible -- to represent fusion as being able to supply any commercially significant amount of power within the next several decades -- if ever. Maybe so, maybe not, but we'd better not depend on it.

I'll close this discussion with a comment from a professional ethicist:(1)

> The real debate is about the kind and quality of life
> that make survival worth having.

With nuclear power or without it, there will be social change. The nature of these possible changes must be recognized and decisions must be made.

ASSUMING THE PRODUCTION OF NUCLEAR WASTES, WHAT ARE SOME ISSUES OF VALUES

It is difficult to separate ethical from technical considerations. At the least it is necessary to have some perception of what the technical situation is before one can proceed very far to sort out the social implications. This author neither has, nor pretends to have, the ability to subject the radioactive waste management situation to a disciplined analysis resulting in some clear, and reasonably complete, summary of the social, ethical and moral issues involved. The best that I can do is to suggest some of the problems that I have attempted to resolve for myself.

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(1) M.M. [illegible], "Nuclear Energy Debates: Liberation or Development?", The Christian Century, July 21-28, 1976.

Is it possible to expect complete containment? To date, the management of nuclear wastes has included sizeable releases to the environment. Some long-lived nuclides, e.g., tritium, carbon-14, krypton-85, are routinely released either at reactors or during reprocessing. Other wastes are being sequestered rather casually, e.g., uranium mill tailings, solid wastes buried at Maxey Flats and elsewhere. There have been releases from the high-level waste storage facilities, e.g., at Hanford. Should the nuclear industry persist and expand, the human exposures from these sources will soon reach levels that have been considered to be unacceptable in other contexts.

Consider for a moment the prevailing view of waste management -- pollution control -- in general. It is regarded as an economic problem. The absolute containment of wastes is not seen as making economic sense. The pollution control literature has many statements of the various methods to arrive at an economic balance between control and releases. The statement below is illustrative:(1)

> The correct issues is the optimal degree and type of pollution, the optimal mix of environmental effects, the optimal degree of personal abuse via work or loss of leisure.... The correct problem is that the optimal degree of pollution is not ascertainable, because we do not yet know how to determine the values of relative amounts of pollution -- and persuade the public to heed those values.

As to the growing importance of technology and the declining importance of the environment, two examples from the recent economics literature are noted. The first sentence of the Journal of Economic Literature's 1976 survey of the literature of environmental economics is:

> Man has probably always worried about his environment because he was once totally dependent on it. (emphasis added)

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(1) A.A. Alchain, in No Time to Confuse, Institute for Contemporary Studies, San Francisco, 1975, pp. 22-23.

And, in a 1974 article, economist Robert Solow assures us that thanks to:[1]

> the productivity of natural resources increasing more or less exponentially over time [it is to be expected that] the world can, in effect, get along without natural resources.

Unless there is a radical departure from established practice, we can expect the decisions regarding the management of radioactive wastes to be made in the context of the above remarks. Growth in energy use is imperative for upon it depends the continued domestic health, and national defense. Hence, it must be used and we can not be deterred by uncertainties in waste management. Waste management is regarded as a non-productive activity. Economic reality dictates that some "optimal" balance be struck between degree of control and waste releases. This balance is a changing one, dependent in large part on the values associated at any given time with infringing upon the productivity of the enterprise in question. Under or currently accepted regulatory schemes, the absolute quantity of wastes which are released tend to be proportional to the magnitude of the activity producing the wastes. Also, in this framework, there will be a technical solution, or at least fix, and further, maintaining the health of the biosphere is of decreasing importance. This set of assumptions is getting us into difficulty with the management of wastes in general. It may also be responsible for the inadequacies of past and current practices in management of radioactive wastes. What it amounts to is that by releasing radioactive wastes into the environment we have been trading small marginal gains in present welfare for large marginal losses in future welfare from reduced or impaired ecosystem services. Economics cannot demonstrate that such is not the case -- present benefits are measurable and future costs are not. To be sure, there exists in the economics literature discussions of infinite prices, and also of zero discount rates, for special situations, but I know of no example of these being applied in the real world.[2]

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[1] Robert Solow, "The Economics of Resources or the Resources of Economics", American Economic Review, May 1974.

[2] One would be in error to conclude from all of this that the nuclear option is the only energy source which raises new, and fundamentally different, waste management questions. The release of the carbon dioxide which is inevitably produced when fossil fuels are burned has the potential for causing major, global climatic changes. Such changes could also be exceedingly disruptive.

How absolute, very long-term, containment fits with the current economic dogma that "the correct issue is the optimal degree and type of pollution, and optimal mix of environmental effects..." remains to be seen. Private expenditures that do not increase private profit are only grudgingly made, regardless of the social necessity of doing so. This defect is being addressed with pollutants in general, but can we permit a comparable situation to continue with nuclear waste? Although it has been demonstrated -- usually after the activity was rather extensive and the quantity of wastes released likewise large -- that other pollutants induce cancers and genetic damage we know from the outset that nuclear wastes have those properties. It may be possible, in principle, to decide what level of personal abuse the individuals participating in a decision are themselves willing to accept, for example via risk of cancer, but it is not so easy to decide on an "optimal level" of damage to the genetic pool. With radiation and other insults there is a lack of moral sensitivity to future, random, deaths now discounted heavily both because of being in the future and because of being random. The present value of kilowatts are not discounted but future deaths are -- an ethically very questionable situation.

How about management by "dilute and disperse"? An old and cherished method of waste management is to "dilute and disperse". At first glance, it would appear that this practice has been rejected in the case of nuclear wastes -- but it has not. As has been noted, certain of the wastes, e.g., tritium, krypton-85, carbon-14, are routinely released from reactors and reprocessing plants. There will be renewed interest in these routine releases with attempts to expand the general nuclear power activity, with eventual recognition that there is environmental buildup of these wastes even at the current level of activity, or with the possible publication and verification of new research relating the incidence of malignancies and genetic changes to radiation exposures. Also, those isotopes which are most persistent (and quite incidentally the most toxic) are those which are most suitable for many commercial purposes. Is not using, e.g., plutonium-239 in cardiac pacemakers, cesium-137 sewage sludge or food irradiation;(1) strontium-90 as a local heat source to power thermoelectric devices; or neptunium-237 in timepieces not a variant of "dilute and disperse".

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(1) In an appendix to the Ramo Committee report noted previously, Edward Teller notes, "Scale-up to widespread use of these techniques could utilize most of the cesium-137 available in the near term."

Should we be permitting such uses -- which necessarily involve distributing throughout society a large number of individually small packets of highly toxic radioactive materials -- particularly when we have been unable to devise acceptable management strategies even when the materials were under relatively tight control?

Who will be (is) responsible for the wastes? Who can assume responsibility for assuring that "there is no reasonable chance of radioactivity escaping to the environment through imperfect technology, acts of God, sabotage or other causes"? At an almost trivial level, compared with the situations which could evolve within a few decades of rapid nuclear proliferation, the current situation with the wastes at the now-abandoned Nuclear Fuel Services Plant in New York State serves as an example. The utilities which produced the waste disavow any responsibility. They had contracted to have it carted away, reprocessed, and stored. Now the "someone" seems to be rather undefined. It is even claimed (based on an admittedly incomplete record of civilization) that nation states themselves do not persist forever, say nothing of governments.(1) Does this suggest that we must either establish an institution which is likely to persist independent of the stability of nation states or governments or else seek a waste storage strategy the integrity of which is completely independent of human maintenance and surveillance? Do such exist?

Should the wastes be retrievable or irretrievable?(2) If we can assume that our social structure will persist unperturbed, we can probably use engineered surface storage with ease of retrievability. This option retains options, for example should it at some future date be possible to subject the wastes to treatment. On the other hand immediate irretrievable storage guards against an irresponsible society at a cost of increased environmental risk. Deciding which to choose

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(1) At the risk of overdoing it with Swedish examples, an episode of the recent political campaign serves as an example. Last spring the then prime-minister Olof Palme in an interview indicated that he would assume responsibility for the nuclear wastes. This prompted the speculation that Mr. Palme's party, which had been in power for some 40 years, had plans to remain at the seat of government for a good bit longer. The government fell on September 19, 1976.

(2) This question is a paraphrase of part of a longer discussion in A.S. Kubo and D. [illegible], cited on page 5, *supra*.

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depends on our assessment, not only of technical options, but also of future social stability and our responsibility toward future generations.

What of totally engineered systems? Is it necessary to go to a totally engineered system, even in the short run? What are the assumptions about managerial stability, or social stability, of a system which depends on a "nuclear priesthood" or a "dedicated cadre" which is, by definition, relatively isolated both physically and socially? True, there are precedents for example, in the military. And there are also examples of what may occur for example, the war in Southeast Asia.(1)

Further examples come from the human or social services. We assume across a wide spectrum of issues that our so-called "needs" will be handled best by those who know better -- by those who have claimed a particular problem as their domain. The result of this assumption in far too many cases is a sense of confusion, isolation and impotence on the part of the client. Clienthood assumes incompetence, dependency, and control. Democracy, on the other hand, requires individuals who understand their problems and believe in their capacity to act on their own behalf. Good clients make bad citizens and what we desperately need now is good citizens. Some technologies also make bad citizens.

What legacy should we leave to future generations? Any of the waste management options (except shooting the waste into space) seems to carry the implication that future generations, for a long time if not in perpetuity, must assume the burden of assuring absolute containment. Is this an unreasonable legacy?

Where will the wastes be put? There is not exactly a clamor from the public intended to encourage the location of nuclear waste repositories near them. The reaction from Michigan to announcements that sites there are to be evaluated for their potential as high-level repositories is typical. How will the land-use decisions be made? Who will have to assume the risks associated with proximity to these wastes? It should be noted that this issue is being raised in other energy-related contexts. No one seems terribly anxious to live near, or to move to accomodate the siting of, power plants, refineries, transmission lines, or a number of other facilities. Will arriving at the "optimal level of personal abuse" necessitate what will be considered to be coercive methods carried out under Federal authority?[1] Perhaps coercion is not inevitable. The traditional way to handle a population which is not responsive to the first overtures toward their moving to accomodate "development" is to either use eminent domain (police powers) or to buy them out. There is growing evidence, for example with high voltage transmission lines that these approaches are not working. If coercion and physical displacement to accomodate radioactive waste storage siting is deemed "necessary" the logic will be something like "national security" demands nuclear power which inevitably produces the radioactive wastes which require some "waste management" which must be conducted somewhere and "this" is the best place so "you" must be moved. This is prison logic. These are prison ethics. But, who are the prisoners?

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(1) For a highly precise discussion see, e.g., D. Halberstam, The Best and the Brightest, Random House, New York, 1972.

When must there be candor? The record of nuclear development contains many instances when the public was not kept fully informed. Examples range from almost amusing cosmetic changes such as "hazard analysis" becoming "safety review" to overt suppression and distortion. There have been soothing conclusionary statements to accompany virtually each reported environmental release of radioactive materials or the announcement of proposed sites for nuclear facilities, e.g., the proposed Lyons, Kansas, repository. During reactor "incidents" (are there never accidents?) for example at Brown's Ferry or Detroit Fermi the public was not kept informed, although evacuation could have been necessary. There is clearly a problem with reconciling objective reporting of health hazard, or potential hazard, and the risk of public panic or the risk of making this new technology seem unattractive. In instances when candor has been attempted, the information has been used as evidence that the activity is "unsafe". For example, a few days ago I reviewed a report written by a student public interest group on the operating history of a specific reactor. They noted that there had been a large number of scrams at the reactor over the years and had interpreted it to mean that each scram was associated with a potentially hazardous event and hence many scrams constitutes evidence of unsafety. It had never occurred to the authors that there could be other, much more benign, explanations. If a public education campaign is finally to be started by this industry it must include the good as well as the bad, it must include understandable descriptions of what things mean, and it must be candid. But, at least for awhile, there will be a high tax on telling the truth.

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[1] A couple of years ago a Palestinian social scientist visited the University of Minnesota and made a number of appearances to discuss his particular interests. During one of these discussions he drew an interesting, albeit speculative, [illegible] between his people and people in the United States who would be forcibly removed from their land to make way for energy developments being [illegible] to support values which they did not share.

WHAT IS THE RECORD?

Considering the waste management implementation questions that I was asked to talk about here today, I was reminded that the first exposure that I had to the public policy side of nuclear power involved the management of wastes from a nuclear power reactor. In early 1968, a few weeks after beginning to think about public policy issues associated with reactors, I was concerned about estimates of the environmental releases of tritium expected from a boiling-water reactor. There was a discrepancy of several orders of magnitude between "expert" testimony which has been made before the Minnesota Pollution Control Agency, internal reports of a major reactor vendor, and computation which I had made. As it turned out there was a potential problem with tritium, but in the context of reactor licensing in 1968 it should not have been a significant issue. It became important, however, because the anticipated releases had been misrepresented in testimony before a public agency. Because of that the public's faith in the adequacy of then current practices in the management of routine releases of radioactive wastes from atomic reactors was reduced, and other questions came to be asked. The *only* reason that the tritium issue was even raised was because there was evidence that the magnitude of these releases -- however large or small, important or unimportant -- had been misrepresented. Tritium management was important not because of substance but because of process.

Could it be the same with the general management of nuclear wastes? Could it be that the process will prove to be more important than the substance? Consider the record. Over the past several decades there have been assurances, *ad nauseum*, that there is no problem with the management of nuclear wastes. Is it not strange that in some cases, for example during consideration of major reactor accidents, we are admonished to look at the record -- but there are no such pleas when waste management is the topic of inquiry. The record here is different, containing: supression of the NAS report;[1] Maxey Flats; Hanford; Lyons, Kansas; higher than expected levels and giant sponges; wet holes in New Mexico; leaking drums at Rocky Flats, reprocessing at Morris, Illinois, and West Valley, New York; . . . . Is it that the problems are exceedingly difficult? Is it that the nuclear establishment has not really tried to resolve waste issues but has simply responded with a facade of paper? Or, is it that our institutions are simply not tuned up to deal with a waste product which is not amenable to the traditional approaches? It is a disgrace that almost 15 years after Oyster Creek we appear to be no further along in the management of nuclear wastes. Even the low-level waste management, probably regarded as the least difficult of all of the radioactive waste problems, has, according to the Atomic Industrial Forum, been found to be "shot through with major shortcomings".[2] Our institutions seem incapable of dealing with the issue. Is the problem the substance or is it the process? And, at this stage of the game, who can we trust to be candid? To simply restore confidence in the institutions responsible for the management of nuclear wastes is a social concern which must be given high priority. But, a demonstration of competence must precede the restoration of confidence.

IN CLOSING

In closing this discussion, I would like to pose to each of you the same question that was presented during a TV debate in the spring of 1976 to then prime-minister of Sweden, Olaf Palme, by his challenger, Thorbjörn Falldin:[3]

> Mr. Falldin: "Olaf Palme, can you stand here this evening on this platform and guarantee that you give to the generation of today, to coming generations, a better society when you want to give them a nuclear power society? Can you give this guarantee here this evening?
>
> (Mr. Palme said nothing.)

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(1) In 1966 the AEC supressed a report of the National Academy of Sciences Committee on Geologic Aspects of Radioactive Waste Disposal, caused the discharge of the committee and the appointment of a new one, with no overlapping membership.

(2) Nuclear Industry, September 1976, p.22.

(3) As quoted, among other places, in the New York Times, September 21, 1976.

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Conference on
Public Policy Issues in
Nuclear Waste Management

October 29, 1976

"IMPLEMENTATION: ACTION OR STALEMATE?"

Eugene B. Skolnikoff
Professor, Political Science, M.I.T.

I

The court opinion that required radioactive waste disposal to be considered in the licensing of reactors gave legal weight to the growing public concern about the management and control of this part of the nuclear fuel cycle.[1] It served to emphasize once again the growing difficulty of dealing with technological issues in our society, issues that raise central questions of decisionmaking, of management, and of regulation.

In fact, the ability to reach decisions about technically complex and necessarily risky issues, and to proceed with implementation of those decisions, is becoming one of the central concerns of governance in industrial societies. It is not too strong to state that fundamental values of our political system are at stake. Essential needs must be met. If decision processes to meet those needs become stalemated the pressures for more authoritarian modes of governance will grow. But, the preservation of open decision processes that do not lead to stalemate is a difficult task that is likely to get harder, not easier, in the future.

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1. Aeschliman v. NRC, Nos. 73-1776 and 73-1867 (D.C. Circuit, July 21, 1976).

The management of radioactive waste is an excellent example of a complex and risk-laden issue. It relates to the basic requirement for energy, but also involves long-term questions of safety and control. It is closely tied to issues of national security, and raises emotional spectres of nuclear danger. Moreover, it also has the characteristics of issues that are the hardest to deal with: the level of uncertainty is high, the technology is esoteric and not easily accessible, the evaluations of risk are contentious — even among experts — and the opportunity for demagoguery on all sides of the question is therefore substantial. Moreover, significant economic and political interests are at stake, further exacerbating the problem of dealing with the issue successfully.

Other papers at this conference will be concerned in detail with analysis of alternative policies for radioactive waste management. It is not the purpose here to develop these alternatives independently. Rather, it is to point up what is necessary to reach decisions about those alternatives and to carry them out. Whatever the particular preferred choices may be, any policies considered for radioactive waste management will have to be concerned with several specific considerations that deserve to be singled out:

— The longevity of some of the waste products will appear to create a requirement for unprecedented governmental control of the material. Whether this is in fact a serious technical difficulty is presumably in question and is related to other issues, but the perception of that requirement will undoubtedly have to be reckoned with.

-- The difficulty of handling radioactive waste is bound up with the decision about reprocessing and the development of breeder reactors. The reprocessing of spent fuel elements to recover plutonium and uranium may make the waste physically easier to dispose of, but that policy cannot be decided in isolation from the broader questions raised by the reprocessing issue.

-- Responsibility for nuclear waste management and regulation in the U.S. is divided among many agencies and institutions. ERDA has primary R & D responsibility, and NRC and EPA have the major regulatory responsibility at the Federal level, with the States also involved.

-- Management authority is divided between ERDA and private industry, with the DOD also playing a role. The International Atomic Energy Agency is involved at the international level, but so far plays only a facilitating role for analysis and consultations on waste management issues.

Any resolution of waste management issues will require attention to the capability of institutions to carry out management and regulatory tasks. Even a decision to halt nuclear power development in the U.S. would not avoid the problem since there is already considerable waste from existing power reactors and military programs in temporary or questionable storage. And other countries will proceed with nuclear power, whatever the U.S. decides.

It is possible that a new institution for management of nuclear waste will be necessary in the U.S., either by expanding the responsibility of an existing agency, or by creating a new "authority" for that purpose. Institutional development on the international scene may also be necessary.

-- The concern over the length of time for which nuclear wastes continue to pose hazards has a reverse consideration. Should storage be carried out so that the waste is retrievable for better disposal as waste disposal technologies improve, or to allow the possibility of recovery of the stored energy by a future generation, in the case of unreprocessed fuel rod storage? The time scales involved in radioactive waste seem to lend an unusual caste to the choices involved, though in fact management of hazardous stable chemicals have some similar characteristics.

-- Radioactive waste storage must be concerned not only with the disposal of spent fuel and its byproducts, but also with contaminated plants and other facilities no longer operating. Thus, a major factor in the design and licensing process for power reactors will have to be the plans for dealing with the plant after its useful life, an issue likely to arouse considerable local controversy if plants have to be left sealed for any substantial length of time.

In attempting to come to grips with these and related issues in the policy process, and to carry out the decisions reached, there are a number of observations about technology in the public arena that need to be kept in mind.

1. There is no such thing as a riskless technology.

This is obvious, but the subtle characteristics of risk associated with particular technologies often make acceptance of risk difficult in practice in the political process. The risks associated with technologies already in place are often ignored when new technologies with evident risks are being considered; the patent risks of a new technology are not easily weighed against the much less certain risks of foregoing the technology; the risks of a new technology are easily seen and may arouse emotional reactions because of their nature rather than their scale (particularly relevant to nuclear technologies); the new risks may threaten different segments of society than do those of existing technologies; the risks of new technologies have different characteristics (e.g., individually assumed vs. socially imposed) than those that are already part of everyday life.

Obviously, we are dealing here with comparisons of risks and of benefits associated with those risks. But this is not a wholly quantitative comparison, even if all the information about the technologies and their effects were available. Risk comparisons are partly quantitative, dealing with apparent matters of fact, but are also bound up with emotional, economic, political and personal aspects that are necessarily subjective.

8. Agreement by experts on the risks associated with use of specific technologies is not to be expected, even for those aspects that are apparently amenable to quantitative assessment.

It is obvious that if overall risk assessment is subjective, it must involve matters of value as well as fact so that one would not expect agreement *a priori*. But, why is agreement even on the quantitative or factual aspects not usually or easily achievable?

The problem is simply that policy choices involving new technology are concerned with future actions and thus necessarily involve uncertainty. That means that assessments involve extrapolations of present information (which itself may be imprecise or in dispute), and therefore depend on judgment, analytical competence and imagination. All of these not only vary from individual to individual, but are also affected by an individual's attitude or stake in the issue and in its broader implications.

The range of disagreement to be expected is not predetermined, it will vary with how much is known, how big a step from the present is being proposed, whether there is agreement on what the issue actually is, and how much testing, experimentation and study is possible. A rough consensus among *most* of the experts is possible if a great deal is known about the technology, the issues are reasonably clear and agreed, the number of relevant professions small, and the non-technical stakes are not too large (compare the fluoridation controversy, for example, with debates over nuclear safety). Of course, on new complex issues, these conditions are rarely satisfied.

In general, the more significant the technological step under discussion, which usually correlates with the importance of the issue in social terms, the less likely there is to be agreement by the "experts" on the definition of the issues and on the technical aspects. Uncertainty *can* be reduced through research, but it rarely can be removed entirely in advance since in large part that could only be done by actually introducing the technology and observing its effects. Even that is not sufficient where scale or long-term consequences are the basis of important disagreements.

Unfortunately, it is also unlikely that disagreements among experts will be sharp and amenable to clear exposition. There are likely to be variations in the competence of "experts," and the relationship of any important technological issue to broader concerns usually guarantees that different groups will see the questions in different terms.

3. No one who has become a party to a public policy debate can remain completely disinterested, so that bias or point of view necessarily color risk assessments.

There is a corollary to the preceding point in that the existence of inextricable value aspects of most issues implies that completely disinterested analyses by experts, or for that matter by any parties to an issue, are not possible. Obviously, this is a matter of degree, and is affected by the extent of an individual's involvement and the signficance of an issue. But, scientists as well as politicians are not immune; scientists too, are likely to be influenced in their professional judgment by their policy preferences. In fact, it is not uncommon to observe scientists and others use their expertise in an advocacy role, consciously or unconsciously using information selectively. This does not mean there are no important and useful benefits to be realized by going as far as possible to reach agreement on the technical aspects of an issue; quite the contrary, but the limits must be recognized.

Note that the inevitable existence of bias applies to all parties of interest. Public interest groups are also strongly affected by their goals and their environment as are industry or government representatives. George Wald's implication that nuclear power skeptics are more likely to be right because they have "nothing to gain" should not be accorded weight (for that reason) in evaluating arguments regarding the risks of nuclear power.[2] Conflict of interest is pervasive, insidious, and also subtle.

The problem, of course, is not to rule out all analysts as ineligible, but to determine how to proceed recognizing that on important issues most people are interested parties.

4. The participation of the lay public in technological decisionmaking does not guarantee sensible decisions, nor that there is understanding of the issues involved.

Public participation in decisions about technology can have many justifications. The most pragmatic are the public's increasing wariness about the effects of new technology,[3] and the growing need to allow participation by interested parties in order to reach decisions that are, in fact, acceptable.

But, this objective of greater public participation often founders on lack of responsible attention by the public, or is reflected in plans for unrealistic citizen feedback schemes,[4] or involves groups who do not necessarily reflect the views of those they claim to represent. Time, attention, interest, and competence to understand the details are often lacking; and factors such as manner of presentation, personality of the protagonists, skepticism of authority, and often widely varying personal objectives (such as employment vs. environment) condition the quality of public participation, especially when — as is almost always the case -- public exposure time is extremely limited.

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[2] George Wald, NYT, February 29, 1976, p. E-15.

[3] LaPorte and Metlay, "Technology Observed: Attitudes of a Wary Public," Science, Vol. 188, April 11, 1975, pp. 121-127.

Inevitably, therefore, the public, or rather the different publics, must have available formal or informal means to be "represented." If elected representatives are not sufficient representation, and increasingly they are not, other means and institutions are necessary. And the representation must be such that it provides, and is seen as providing, effective participation in the decision process.

> 5. Access to relevant information and analysis is a necessary though not sufficient, condition for effective participation of interested parties (or their representatives).

When dealing with high technology issues, there is often a natural monopoly of relevant information and competence on the part of government or industry with the greatest stake in proceeding with the technology. At the same time there are usually few individuals outside the immediate protagonists who can digest technical information, reduce it to policy terms, ask the relevant questions, understand the alternatives and participate meaningfully in policy discussions. The public debates over weapons systems in recent years were only made possible because former government and industry employees with both experience and knowledge elected to enter the lists.[5]

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[4] Leonard et al., "Minerva: A Participatory Technology System," BAS, November 1971, pp. 4-12.

The need for information and analysis to be more widely available may be just as difficult to meet in unclassified civilian technology areas, even without security problems; it is essential that it be met. It will require conscious measures to make information available, and to build a cadre of analysts able to use the information.

It is counterproductive for the protagonists of a technology to assume they are better off if the public at large is ignorant about a technology, leaving decisions to knowledgeable experts. Today's skepticism about the effects of technology coupled with technological ignorance leaves society prey to demagoguery. The absence of trusted responsible analysts enhances the power of irresponsible analysts, just as the absence of trusted, responsible protagonists of technological systems enhances the power of special interest groups in industry and government.

Disagreement among experts who have been given access to information certainly complicates the problem of reaching decisions, but it is even more dangerous to allow opposition based on fear and ignorance by withholding information. The challenge is to build a process based on information and knowledge so as to be able to reach acceptable policies, even if they are not necessarily optimum from any single point of view.

That injunction leads directly to the final proposition which in many ways is a prerequisite for reaching effective agreement on complex, risky, but needed technological action.

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[5] Anne Cahn, Eggheads and Warheads, Scientists and the ABM. (Cambridge, C.I.S., M.I.T., 1975)

> 6. The willingness of a society to accept a technological decision that is not fully understood and that carries the risk of unfavorable consequences along with its benefits, even when there has been adequate opportunity for debate and participation, depends fundamentally on the existence of trust and confidence in the essential fairness of the society.

No efforts at public participation, discussion, dissemination of information or other measures with regard to a complex technology carrying possible risk, will be of much use in achieving willing acceptance unless there is a substantial degree of trust in the system. In the not too distant past, decisions by experts with little public discussion were relatively easily accepted. Early decisions about nuclear power, many technical military and foreign policy choices, and others in complex technological areas were made with little public debate. The experts had legitimacy; they were trusted to represent all interests on subjects not accessible to the public at large, and it was assumed the issues could be treated largely as technical questions.

But that trust was later seen to be misplaced; some decisions turned out to be representative only of specific interests, others turned out to be made on too narrow a base of knowledge or analysis, and some had serious adverse consequences. As a result, we are in a new era in which the testimony of experts, especially those in government or industry, is often devalued, challenged, suspect. Yet, that, too, must not be allowed to last, for immobility is also a decision and may also have serious consequences.

There must be a middle ground in which there is sufficient openness to explore issues adequately, and sufficient trust to reach closure on a debate and accept a decision even when that implies injury to some parties at interest, or more general risk to the society. That can only happen if the process of decision is, and is seen to be, fair, which also means that it represents everyone, or at least those most affected by the decision.

Willingness to share information, to open issues for discussion, to bring in the public early and honestly will contribute to rebuilding that trust and confidence. But it must be recognized that this is a broader issue that relates to the society as a whole, not just to technological questions. In that sense, the ability to involve the public successfully in decisions on and implementation of policies for nuclear waste management is dependent on deep-seated developments in the general political climate in the U.S. There is only a limited influence that the manner of dealing with this particular issue can have on that larger question of trust in the system.

II

Implications for Implementation

What are the implications of these propositions? Our goal is to be able to reach decisions about a technically complex and necessarily risky issue — radioactive waste management — and to be able to implement those decisions. Let me briefly recapitulate the propositions:

- a riskless technology is not possible;
- agreement by the "experts" on the risks is not to be expected;

-- no party to a public policy issue is completely disinterested;

-- public participation does not automatically mean understanding and acceptance;

-- access to information and analysis is essential for participation; and

-- trust and confidence in the political system at large is a necessary prerequisite for reaching and carrying out decisions about controversial technology involving substantial risk.

To what policies and measures, when combined with the specific issues involved in waste management, do these propositions point?

It is obvious than there are no panaceas. In part this is so because, as noted, the ability to deal with this issue is dependent on broader questions of attitude in the society at large. In part it is because the technical issues of nuclear waste management cannot be separated in the policy process from the issues associated with nuclear power, such as the need for reprocessing and breeder reactors, or from the licensing of reactors themselves, now mandated by court decision. Nor can they be totally seperated from larger social issues such as energy policy, nuclear proliferation, economic growth, inflation, and Middle East politics. And in part it is because there are no short cuts nor assured outcomes of an open policy process.

The major thrust of the arguments is simply that the policy process must be, and be seen to be, open and fair. That will not guarantee that closure can be reached on decisions and that those decisions can be implemented, but it is increasingly a necessary aspect of the decision process.

There are a series of approaches and policies that are relevant to the goal; I will attempt to spell out a few of the more important in brief compass.

1. Open Policy Discussions Starting at Early Stages

This is an obvious, if general, injunction which, however, is not easy to carry out. It has little meaning unless other steps are followed to make information and expertise available outside government and the involved industry (suggested below). And there is necessarily great difficulty in defining where confidentiality and secrecy are legitimate. All deliberations in government cannot be open: that results either in immobility or the development of different forms of internal communication (telephone calls instead of memos, few formal documents, etc.). Industry also has legitimate need for protection of proprietary information and of development of corporate plans.

But, self-conscious efforts can be made to create opportunities for meaningful public discussion of policy options *before* decisions are reached. As noted, it is important as well that these efforts be *seen* to be honest in that they are genuinely held before agencies have decided on their policy choices.

Policies for management of nuclear waste will now necessarily be aired in the hearings required in the licensing process for power reactors, and in the development of environmental impact statements. In fact, it seems likely that waste management will become a major factor in reactor licensing debates. It would be a mistake to think of these hearings as the first step in obtaining public inputs in the decision process. Rather, through means mentioned below, there should be ample opportunity prior to hearings to elaborate options, encourage independent analysis, and engage in public discussion.

8. Involvement of Other Institutions

The development of analyses and options should be carried out not only inside the government and with industry that is directly involved, but also with other institutions, such as universities and technical analysis firms. This can serve the multiple objectives of making information and analysis more generally available; of providing more options, from a variety of perspectives, for consideration in policy deliberations; and of contributing to consensus-building among institutions perceived by the public to have less of a stake in particular policy outcomes and thus in some sense serving as their representatives.

Inevitably, if the government sponsors such analyses, it will mean supporting studies carried out by groups that may ultimately turn out to be critics of the policies chosen. If the studies are in fact sponsored before decisions are made there may be enough reflection of them in the decisions to minimize opposition. In any case, one can hope that competent studies will serve to make disagreements clearer and more easily debated.

Since disagreements and varying assessments are unavoidable, any steps that sharpen the real issues under dispute are likely to reduce confusion and make choices easier.

The need for widespread involvement means that on important issues it would be wise to commission studies by more than one outside institution. There is nothing wrong, and much to be gained, by seeking analyses on the same issues from multiple sources.

Government support for analytical studies also carries some dangers. Over time, it may influence the attitudes of those who become dependent on continuing funding and thus become a way of co-opting potential critics. Providing for diversity of sources of funds from government can help to alleviate that danger; better yet are analyses wholly supported from private resources.

3. Outside Reviews of Major Policy Analyses

When a government agency commissions a major study it intends to use as a basis for policy decisions, it should also fund outside reviews of that study to develop comments and highlight issues.

The commissioning of WASH 1400 (The Rasmussen Study of reactor safety) did not satisfy that criterion, and the positive contributions of that report may be reduced as a result. This study, dealing with an obviously complex and central issue, was opened for public review and criticism before being put in final form, but outside analysts were expected to find their own resources. Gradually, after final completion of the study, some questions have been emerging, now without adequate opportunity for discussion and debate before the conclusions have been "accepted" as the basis for government policy. The result is to put into some question the credibility of the entire analysis, whether warranted or not, and to give a weapon to critics of nuclear energy that can go well beyond the actual deficiencies of the study.

4. Public Forums

Public forums, presumably such as this one, held frequently or on a continuing basis can provide occasions for airing of issues, for expressions of the views of various groups, and for feedback. Again, these will mean little unless there is adequate information, and resources available for analysis outside government or industry.

5. Continuing Regulation and Control

The nuclear waste management problem appears to require continuing political regulation and control to an unprecedented degree. The most dramatic aspect is the persistence of the hazards over time scales well beyond the lifespan of recorded society. That implies that the measures for dealing with waste must not necessarily be dependent on organized human intervention, but does not automatically mean the risks cannot be made acceptably small.

Clearly this aspect of the subject needs to be given special attention early in public studies and discussion. It appears to be a rather novel issue of public policy, though not in fact so different from problems of dealing with toxic chemicals, and certainly is easy to dramatize beyond its actual significance.

It may well be wise for this reason alone, if for no other, to create a new government body for the management of nuclear waste that has single-minded responsibility for the problem. That will serve to enhance the priority accorded to the issue over a longer time, and also help to separate promotional objectives for nuclear power from management objectives for handling the waste products.

Another aspect of the problem of regulation is more traditional, whether entrusted to existing agencies or shared with a new body. The history of regulation in the U.S. shows how easily the original basis of operation of a regulatory agency can gradually alter until it becomes the captive of the segment of society it was designed to oversee.

The reasons for this "capture" are to a considerable extent natural, for over time the only groups who sustain interest and knowledge in a subject are likely to be those with a specific stake in that subject. Others lose interest, have other concerns, and find the difficulty of maintaining continued competence in the subject too difficult. Thus they more easily accept (or don't even notice) the gradual narrowing of the decision process whether that happens naturally or by design. Until, of course, there is some crisis or catastrophe, when it may be too late.

This narrowing of the regulatory process is inappropriate for most technologies, and particularly so for nuclear technology and its waste management aspects. There are no sure ways of preventing this from happening, though assignment of management authority to a single agency may give the regulatory problem more continuing visibility and thus more attention.

Another, more ambitious course of action, is to develop institutions outside those directly concerned with management or regulation that have responsibility for analysis and challenge to government policies. Regulatory agencies are more likely to be independent regulators if interest and knowledge about a subject is more widespread. Some steps along these lines have been suggested earlier; other ideas of an institutional nature are offered below.

6. Congress

Congress increasingly provides a route for the expression of public concerns, for the dissemination of information and policy options. In addition, Congressional resources for independent analysis of technologically-related subjects are improving, through the creation of the Office of Technology Assessment (OTA), strengthening of the Congressional Research Service and the General Accounting Office, development of the new Congressional Budget Office, and the possible establishment of a policy studies organization for the Congress.

Congress thus is coming to have the competence to develop analyses of issues and proposed policies that can provide some of that counterweight to the dominant technological capability of Executive Agencies and of industry. In this role, it can serve as a route for expression of general interests, and as a means of maintaining technical competence outside government and industry in complex technological areas.

Conscious development of Congressional resources for this purpose could also be a route to stagnation if the result is increased Executive/

Congressional confrontation. If, however, the Executive Branch recognizes the role the Congress will play in questioning its policy recommendations on technologically-related issues and therefore reaches out earlier for more public involvement and debate, the results should be better and more timely agreement.

The studies carried out under Congressional auspices are more likely to reflect the views of interests outside the agencies or of directly-involved industry. Thus, if those interests have already been involved in policy discussions there is some greater likelihood of the development of the consensus needed for action.

These Congressional resources can also play a role in the regulatory process in the sense of being alert to problems that emerge once the technologies are in place. OTA specifically has such a responsibility, and could be a useful buffer against narrowing of the decision base with time.

7. Development of Institutions for Advocacy and for Objectivity

As society becomes increasingly committed to complex technology, the problem of competent criticism in an adversary political process becomes ever more difficult. The rationale for this paper can in fact be thought of as stemming from that growing problem.

An interesting question, going well beyond what can be discussed in detail here, is whether and how the government in a representative democracy should see itself as responsible for the creation and maintenance of institutions designed to be analysts and critics of government policy and of the regulatory mechanisms established by government. Many institutions perform those functions now, especially universities and public interest groups, but the resource base is often inadequate or sometimes raises conflict of interest questions.

Can (should) government agencies provide funds for institutional support of their critics? Can it be done in ways that avoid loss of independence over time? The NSF and NRC presumably would be more likely sources of continuing funds free from influence than would, say, ERDA or NASA. Would Congress accept such a mission, or should it provide funding directly as it does for OTA? There have been concrete proposals from some Congressmen and Federal judges for just such funding to outside groups by Executive and regulatory agencies.

In c[illegible]ng the institutionalization of analysis and criticism of government policy, it must be clear that there is not always an obvious distinction between objectivity and advocacy. There is a tendency to deplore individuals, particularly scientists and engineers, who use analysis for advocacy purposes. Presumably, that is because it implies distortion of the analysis, or at the least selective use of information. As noted in the earlier propositions, however, there is inevitable pressure leading to bias, or something less than disinterestedness, as soon as a person becomes a party to a public policy issue.

However, that does not mean we are doomed always to discount everyone's views (with whom we don't agree) as hopelessly biased. Here the traditions and mores of the scientific community and of the universities become very important.

For what the society needs is both institutions for advocacy and for objectivity. The existing base of individuals competent to understand high technology issues and their implications is narrow. That implies

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that groups involved in such an issue but not adequately represented in the government's decision process are likely to be underrepresented. Individuals or institutions able to work with the technology, and that have access to information, are needed in that avowedly advocacy role to represent those interests.

But then also needed are institutions outside of government able to provide a base of expertise not beholden to specific government policies or industrial interests that could analyze issues and provide a basis for resolving disagreements. Complete objectivity is not achievable, but over time a striving for disinterestedness and reliance on scientific norms could bring confidence in such institutions and help them provide a needed mediatory capability. Their authority would come from expertise and confidence built up over time, not from any formal grant of responsibility.

Whether such instituions should be sought among those that already exist, or new ones created, or both, deserves much attention and discussion. The "science court" is presumably one such proposal, but in my view is not a likely success, and may even be a diversion. Other ideas are possible or have been suggested and need development. My own guess is that existing institutions, in particular universities, the National Academy of Sciences, and research centers, already engaged in the task, are more likely candidates.

The judicial process in the U.S. is also becoming a major "institution" for the resolution of disputes related to technology. The ability of that process to deal adequately with technological issues is very much in question and needs urgent attention and, probably, invention. The development of institutions competent to deal with technologically-related policies and accepted as disinterested and reasonably objective, could have an important role to play in the judicial process.

I am impelled in this discussion to point out the cost to the authority of science and technology of having scientists and engineers operating in both advocacy and adjudicatory roles. This is likely to be a real cost, but since we already see scientists and engineers in advocacy roles, to the discomfiture of some of their colleagues, there is little to do but accept it and focus on the development of needed institutions. Perhaps others would have different views on this from the perspective of the norms and values of the scientific community.

8. Bringing Industry Along

All too often in the U.S. today, attitudes toward business are polarized, with many seeing industry as dominated solely by improper motives, and others uncritically arguing for reduced regulation of industry.

In fact, a technological society requires change and technological innovation. The source of that innovation, which is largely in industry, can be adversely affected by a system that makes change too difficult, or removes the incentives for innovation. But imposition of restrictions with such effects can be prevented from happening only by reestablishing the trust, the reasonable confidence, that the policy process will reflect the concerns of all interested parties and not only those with narrow economic interests in the outcome.

Industry, then, must be very much a part of the measures for openness described above. Industrial motivations and objectives must be adequately, and fairly, represented in the process. That also implies a willingness by industry to recognize the need for full and informed parti-

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cipation by other interested parties, including those who do not share the same objectives on particular issues.

III

Radioactive waste management represents the kind of technologically complex and risk-laden subject that cannot be isolated from the social issues in which it is embedded, and yet which must be dealt with just because of its relation to broader social issues. It is essentially a paradigm for the kinds of central questions with which the society must deal while preserving a democratic political process. And it is particularly relevant because the nature of the technology implies adequate measures over unprecedented spans of time.

The delicate balance between a regressive stalemate and authoritarian decisions about social policy must be achieved. In large measure whether we are able to do so or not will be determined by the ability to build a decision process with competent participation by those concerned and with willingness to accept the decisions that result.

PRESENTATION

TO THE

CONFERENCE ON PUBLIC POLICY ISSUES IN NUCLEAR WASTE MANAGEMENT

BY

ASSEMBLYMAN CHARLES WARREN

CONDUCTED BY THE MITRE CORPORATION
UNDER THE JOINT SPONSORSHIP OF THE NATIONAL SCIENCE FOUNDATION,
COUNCIL ON ENVIRONMENTAL QUALITY, NUCLEAR REGULATORY COMMISSION,
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CHICAGO, ILLINOIS

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PREFACE

Thank you, for the introduction, the welcome and the opportunity and honor of this podium.

Preliminarily I hope I will not appear discourteous or undiplomatic but I think a criticism of this conference should be brought into the open. I have heard complaints that this conference is not adequately or properly balanced in terms of both participation and presentation. I cannot respond to the criticism except for the luncheon speakers.

Frankly, I think the sponsors did their best in finding a nuclear pessimist and a nuclear optimist. Yesterday you heard from the nuclear pessimists represented by the Honorable Congressman John Anderson (ranking minority member of the Joint Committee on Atomic Energy). As you gathered from his remarks, the nuclear industry is in some peril and there does not appear to be a way out--at least none Congressman Anderson identified for us.

Congressman Anderson described the situation somewhat as follows: There is a "record of serious problems" which has been dealt with by "insensitive managers". In response to such record and insensitivity, he said "public awareness and concern is rapidly arriving at a point where a decision must be made". He noted that this decision must be made in a "democratic manner"

DESPITE THE FEELING OF SOME THAT "CRISIS PROBLEMS SHOULD NOT BE HANDLED DEMOCRATICALLY". HE AGREES WITH THOSE OF THE PUBLIC WHO ARE "DEMANDING ANSWERS" AND THAT "WE HAVE SUCH ANSWERS BEFORE WE MAKE A MASSIVE NUCLEAR COMMITMENT". HE OBSERVED THAT "LEAKAGE OF NUCLEAR WASTE HAS CAUSED QUESTIONS TO BE RAISED" WHICH HE BELIEVES ARE "LEGITIMATE".

HE WENT ON TO SAY--

"WE HAVE TO CONFRONT THE FACT THE AMERICAN PEOPLE ARE INCREASINGLY RESTIVE" AND THAT NUCLEAR WASTE "IS A PROBLEM WHICH CANNOT BE PUT ON THE SHELF."; THAT "IF WE DECIDE CONTINUED DEVELOPMENT OF NUCLEAR POWER IS NOT DESIREABLE" THEN "WE HAVE GOT OUTSELVES IN A DANGEROUS DILEMMA."

HE SAID THAT THE TECHNOCRATS HAVE BEEN DEALING WITH THE WASTE PROBLEM "IN A MANNER WHICH THE PEOPLE DO NOT SEE AS BEING ADEQUATE"--AND "THEY WANT TO KNOW". THEY WANT TO KNOW ABOUT "TERRORISM, FUTURE GENERATION RESPONSIBILITY, MORALITY. THEY WANT ASSURANCE", HE SAID "AND WHEN EXPERTS DISAGREE, THEY BECOME CONFUSED".

HE NOTED THERE WERE "OTHER NUCLEAR PROBLEMS AND THE LIST KEEPS GROWING".

UNFORTUNATELY, AT THIS POINT HE SAID HE HAD TO CLOSE HIS REMARKS. BUT I GOT THE IMPRESSION WITH A FEW MORE MINUTES HE MIGHT HAVE CIRCULATED A NUCLEAR MORATORIUM INITIATIVE.

NOW, LET ME GIVE YOU THE VIEWS OF A NUCLEAR OPTIMIST!

This afternoon I will discuss the relationship between nuclear waste management, nuclear fission and national energy policy.

It will be my thesis there cannot be a relevant national energy policy until there is a formal and public assessment of the extent to which nuclear fission is an acceptable energy source with waste management but one of several primary issues.

Responsible consideration of energy policy seems to require this assessment as it is today conceivable that nuclear fission will not play a significant role in meeting future electricity requirements.

To the extent energy policy involves the formulation of a desired energy demand-supply equation, the presumed availability of nuclear power distorts consideration of the role of supply alternatives and minimizes the need for reducing demand through conservation.

Thus, if nuclear fission is assumed to be available to accommodate a third or a half of our electricity demand, then to that extent there is less urgency to consider coal and other resources and our inattention to conservation strategies can be prolonged.

As we all know, current policy assumes unlimited nuclear fission availability. However, there is evidence to suggest this assumption may be short lived. As a result, we may soon discover

THAT NOT ONLY IS OUR COAL DEVELOPMENT POLICY INADEQUATE, OUR ENERGY CONSERVATION PROGRAM NONEXISTENT, BUT THAT NUCLEAR FISSION IS NOT AVAILABLE TO THE EXTENT NECESSARY TO MEET ITS ASSIGNED ROLE.

ASSUME THE SO-CALLED WORST NUCLEAR CASE: THAT NUCLEAR FISSION IS NOT AVAILABLE AS A COMMERCIAL ENERGY SOURCE; WOULD NOT THAT FACT CAUSE A SIGNIFICANT INCREASE IN OUR ATTENTION TO ENERGY CONSERVATION MEASURES? WOULD WE NOT CONSIDER COAL AND OTHER RESOURCE DEVELOPMENT OPTIONS MORE URGENTLY?

IN MY OPINION, AND FOR REASONS CONGRESSMAN ANDERSON DID AND I WILL DISCUSS, IT WOULD BE PRUDENT TO ASSUME THIS WORST CASE, WHILE SIMULTANEOUSLY, CAREFULLY AND FULLY ASSESSING THE ROLE OF NUCLEAR FISSION IN OUR COUNTRY'S ENERGY FUTURE. THIS MEANS THAT DURING THE PERIOD OF ASSESSMENT WE SHOULD BEGIN TO PUT INTO PLACE STRONG ENERGY CONSERVATION AND DEVELOP SUPPLY STRATEGIES AS IF NUCLEAR FISSION IS DESTINED NOT TO BE AS SIGNIFICANT AS NOW ASSUMED.

THIS APPROACH, WHILE ALLOWING US TO KEEP OPEN THE NUCLEAR OPTION, KEEPS US FROM THE OUTER REACHES OF A TECHNOLOGICAL AND POLITICAL LIMB FROM WHICH WE MIGHT SOMEDAY BE UNABLE TO EXTRICATE OURSELVES.

I BELIEVE IT IS ALSO IMPORTANT TO BEGIN THIS NUCLEAR ASSESSMENT EFFORT AS SOON AS POSSIBLE. IN FACT, AND THIS IS IMPORTANT, NOW MAY BE THE ONLY TIME TO DO SO AS LATER IT MAY BECOME IMPERMISSIBLE IF NOT IMPOSSIBLE FOR US TO DEVELOP ALTERNATIVE NONNUCLEAR POLICIES.

IN ADDITION, THE LONGER ASSESSMENT IS DELAYED, THE MORE LIKELY THERE MAY BE A POLITICALLY FORCED DECISION BASED ON

INVALID TECHNOLOGICAL AND SCIENTIFIC CONSIDERATIONS. ALL SHOULD AGREE THAT WHATEVER THE DECISION, FUNDAMENTALLY A POLITICAL JUDGMENT, IT SHOULD INCLUDE ACCURATE SCIENTIFIC AND TECHNOLOGICAL INFORMATION.

LET ME SHARE WITH YOU MY REASONS FOR BELIEVING THE NON-NUCLEAR CASE IS MORE THAN A POSSIBILITY. MOST, IF NOT ALL, ARE WELL-KNOWN.

IT IS CLEAR THERE IS GROWING CONCERN ABOUT OUR PRESENT AND PLANNED RELIANCE ON NUCLEAR FISSION AND THAT THIS CONCERN IS DEVELOPING IN OTHER COUNTRIES. THIS CONCERN AS SOME ARGUE MAY BE FOR REASONS WHICH ARE INVALID. NO MATTER. THE CONCERN EXISTS AND THAT IS WHAT IS IMPORTANT.

THIS CONCERN IS COUPLED WITH AN AWARENESS BY PEOPLE GENERALLY THAT ENERGY RELATED DECISIONS ARE SIGNIFICANT AND MAY AFFECT THEM IN WAYS NOT CLEARLY UNDERSTOOD NOR IN A MANNER NOT NECESSARILY DESIREABLE. THIS AWARENESS AND CONCERN HAS LED TO THE FORMATION OF CITIZEN GROUPS WHO ARE UNWILLING TO LEAVE SUCH DECISIONS TO THOSE WHO HAVE TRADITIONALLY, CUSTOMARILY AND EXCLUSIVELY MADE SUCH DECISIONS. IN A WORD, THE ENERGY DECISION PROCESS HAS BEEN POLITICIZED. NOW POLITICS IS A CHANCEY BUSINESS, SOMETIMES UNATTRACTIVE. IT CANNOT BE CONDUCTED IN A LABORATORY OR IN A MANNER RECOMMENDED BY THE HARVARD BUSINESS SCHOOL, BUT I RESPECTFULLY SUGGEST TO THE TECHNICIANS AND ADMINISTRATORS--BOTH CORPORATE AND REGULATORY--THEY HAD BEST LEARN NOT TO IGNORE IT IF THEY CAN'T LEARN TO LOVE IT.

IN THE PAST SIX MONTHS, THERE HAVE BEEN SEVERAL EXAMPLES OF THE POLITICALIZATION OF ENERGY DECISIONS.

In California, although the voters disapproved a nuclear safeguards initiative, they did so only after the legislature passed three well-publicized bills. Of special interest to this conference is the one which deals with waste management. It provides:

> "No nuclear fission thermal powerplant... shall be permitted land use in the state--until--there has been developed, and the United States through its authorized agency has approved, and there exists a demonstrated technology or means for the disposal of high-level nuclear waste."

In Sweden, Thorbjorn Falldin and the Center Party defeated Olaf Palme and ended 43 years of governance by Social Democrats on a platform which featured opposition to further reliance on nuclear power.

Meanwhile, back in this country, citizens in six more states qualified initiatives which impose barriers to nuclear development. It appears likely these initiatives will be approved in at least three such states and perhaps more next Tuesday.

While voter, and citizens group activity increases, some energy policy professionals appear to be less sure in their nuclear confidence.

The Environmental Protection Agency announces its policy on waste management. It provides:

> "If a safe ultimate disposal method is not found quite soon, expanded use, or even continued

NUCLEAR ENERGY FROM THE FISSION PROCESS WOULD BE VERY DIFFICULT TO SUPPORT."

IN GREAT BRITAIN LAST MONTH, HER MAJESTY'S ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION, CHAIRED BY SIR BRIAN FLOWERS, REPORTED TO PARLIAMENT, AMONG OTHER THINGS, THAT:

> "THERE SHOULD BE NO COMMITMENT TO A LARGE PROGRAMME OF NUCLEAR FISSION POWER UNTIL IT HAS BEEN DEMONSTRATED BEYOND A REASONABLE DOUBT THAT A METHOD EXISTS TO ENSURE THE SAFE CONTAINMENT OF LONG-LIVED, HIGHLY RADIOACTIVE WASTE FOR THE INDEFINITE FUTURE."

IN A PAPER PREPARED FOR THIS CONFERENCE, A NUCLEAR REGULATORY COMMISSION TASK GROUP REPORTS THAT:

> "WE MUST ASSURE OURSELVES THAT SAFE SYSTEMS CAN BE IMPLEMENTED TO MANAGE THE WASTES FROM A VASTLY EXPANDED NUCLEAR PROGRAM BEFORE PROCEEDING WITH THAT PROGRAM."

AND IN ALL RESPECT, IT SEEMS TO ME THIS IS WHAT CONGRESSMAN ANDERSON WAS SAYING TO US YESTERDAY.

NOR HAVE THE COURTS REMAINED SILENT. IN COMMENTING ON THE FAILURE OF INDUSTRY AND GOVERNMENT TO CONSIDER ADEQUATELY THE WASTE MANAGEMENT PROBLEMS, THE COURT OF APPEALS FOR THE DISTRICT OF COLUMBIA IN ITS VERMONT YANKEE DECISION RECENTLY NOTED:

> "IN SUBSTANTIAL PART, THE MATERIALS UNCRITICALLY RELIED ON BY THE NUCLEAR REGULATORY

> Commission...consist of extremely vague assurances by agency personnel that problems as yet unsolved will be solved.... Not only were the generalities relied on in this case not subject to rigorous probing in any form but when apparently substantial criticisms were brought to the Commission's attention, it simply ignored them, or brushed them aside without answer.... This type of agency decision cannot pass muster as reasoned decision-making." (NRDC v NRC, July 21, 1976 -- Vermont Yankee.)

Of equal, if not greater, significance is the attitude of utility managers.

In 1973, they placed orders for 35 reactors; in 1974, for 29 reactors; in 1975, but four! So far in 1976, only two have been ordered.

And just last week, a Wall Street advisory firm (Jesup & Lamont) advised its clients to drop the stock of utilities with a heavy nuclear commitment because of safety and fuel cycle problems hampering licensing and operation (Nucleonics Week, 10/21/76).

All of which indicates to me the need to commence as soon as possible, a formal and public assessment, not just of waste management, but of the role of nuclear fission itself as a factor in energy supply. Some might argue the extent of the inquiry be limited to considerations of waste management. However, waste management is but one of many unresolved problems or issues in

THE NUCLEAR FUEL CYCLE. IF IT IS DEALT WITH EXCLUSIVELY AND IS "SOLVED", IT WILL BE FOUND AS THE HEADS OF THE MONSTER HYDRA--TWO PROBLEMS WILL EMERGE TO TAKE ITS PLACE. FOR THIS REASON, THE ASSESSMENT SHOULD PRUDENTLY BE OF THE ENTIRE FUEL CYCLE, AND ADDRESS AS BEST IT CAN ALL THE UNRESOLVED AND THE UNANSWERED ISSUES.

THE LIST OF SUCH UNRESOLVED AND UNANSWERED ISSUES IS IMPRESSIVE IN BOTH ITS LENGTH AND SIGNIFICANCE. SEVERAL ABSOLUTELY BASIC AND ESSENTIAL ASPECTS OF NUCLEAR POWER ARE INCLUDED.

WE CAN START OUT WITH WASTE DISPOSAL ITSELF. AS THIS CONFERENCE ATTESTS, THERE IS NO COMMERCIAL, DEMONSTRATED METHOD OF DISPOSING OF HIGH-LEVEL RADIOACTIVE WASTES. ALTHOUGH A MEANS FOR DOING SO HAS BEEN SOUGHT FOR 20 YEARS, THERE HAS YET TO BE LOCATED A VIABLE LONG TERM BURIAL SITE; THERE HAS YET TO BE DEMONSTRATED THE TECHNOLOGY NEEDED TO VITRIFY WASTE BEFORE BURIAL; AND, THERE HAS BEEN LESS-THAN-SATISFACTORY SUCCESS IN ISOLATING EXISTING WASTES IN TANKS WHERE THEY AWAIT LONG TERM STORAGE.

OF MORE COMPLEXITY IS THAT WASTE DISPOSAL SOLUTIONS WILL NOT BE SELF-IMPLEMENTING. IT WILL REQUIRE A GREAT NATIONAL COMMITMENT TO PUT A SOLUTION IN PLACE AND IN ALL PROBABILITY PEOPLE MUST BE DEPENDED UPON TO PRACTICE AT LEAST NOMINAL SURVEILLANCE. THE RECORD TO DATE DOES NOT SUGGEST THAT HIGH CONFIDENCE CAN OR SHOULD BE PLACED IN THE INFALLIBILITY OF HUMAN EFFORTS AND THE PERMANENCE OF SOCIAL INSTITUTIONS.

THE WHOLE COMPLEX OF QUESTIONS INVOLVED IN WASTE MANAGEMENT ALONE IS ADEQUATE CAUSE TO DEFER OUR NUCLEAR COMMITMENT SINCE IT GOES DIRECTLY TO THE HEART OF THE PUBLIC SAFETY ISSUE INVOLVED.

The simple fact is that we have not yet demonstrated a mechanism for achieving the necessary degree of isolation even for a few years, far less the time frame of perpetuity characteristic of high-level waste toxicity.

A second unresolved and unanswered issue is reactor safety. While the nuclear industry and federal government seem confident that nuclear is safe, clean, and cheap, the safety guarantees have not been accepted uncritically and this question has sufficient currency to justify review. While there is not time to discuss this issue in detail, it is argued that safety systems have not been adequately tested; problems with quality assurance have not been resolved; and human fallibility insures uncertainty in system performance. The Advisory Committee on Reactor Safety's official list of "unresolved safety items" consists of 27 items still unresolved, including such major questions as pressure vessel failure (PWRs), common mode failures (such as Brown's Ferry), advisability of seismic scram, and emergency core cooling capability.

In rebuttal, it is pointed out that the safety record is excellent and that further reactor safety research will provide the final word. Yet, the prestigious American Physical Society reached the conclusion that the research currently planned gives no assurance of actually being able to resolve the questions which have been raised about reactor safety. No wonder the public is uneasy as Congressman Anderson told us yesterday.

Third, is economics. The costs of nuclear power, particularly investment costs in nuclear power generating stations, HAVE ESCALATED RAPIDLY SINCE 1969. AS A RESULT, NUCLEAR POWER IS NOW ACKNOWLEDGED TO BE ONLY MARGINALLY COMPETITIVE WITH ALTERNATIVE GENERATING FORMS. THE VISION OF NUCLEAR POWER TOO CHEAP TO METER HAS GIVEN WAY TO THE REALITY OF MASSIVE INVESTMENT REQUIREMENTS. THE MOST RECENT OFFICIAL COST ANALYSIS (WASH 1224, DECEMBER, 1974) ARGUED FOR AN AVERAGE GENERATING COST ADVANTAGE FOR NUCLEAR POWER OF ONLY 17%. HOWEVER, IT INCLUDED ALL ENVIRONMENTAL COSTS ASSOCIATED WITH COAL AND ASSUMED UNACHIEVED EFFICIENCIES IN THE USE OF NUCLEAR POWER STATIONS. MOST CRITICALLY HOWEVER, THE 17% ADVANTAGE DID NOT TAKE ACCOUNT OF THE MASSIVE PUBLIC SECTOR EXPENDITURE ASSOCIATED WITH NUCLEAR POWER. EXAMPLES ARE: PRICE-ANDERSON LIABILITY LIMITATIONS; THE TWO-BILLION-DOLLAR-PLUS ERDA COMMERCIAL NUCLEAR BUDGET; AND, COMMITMENTS TO SUPPORT PORTIONS OF THE FUEL CYCLE OUT OF PUBLIC REVENUES INSTEAD OF UTILITY PRICES. THESE PUBLIC COSTS OF NUCLEAR POWER MAY NOT BE RESTRICTED TO THE FEDERAL GOVERNMENT, AS IS DEMONSTRATED BY GETTY OIL'S ATTEMPT TO FORCE THE STATE OF NEW YORK TO ACCEPT RESPONSIBILITY FOR MANAGEMENT OF THE HIGH LEVEL LIQUID WASTE NOW STORED AT GETTY'S DEFUNCT WEST VALLEY REPROCESSING PLANT.

FOURTH, IS URANIUM AVAILABILITY. RECENT RESEARCH INDICATES THAT DOMESTIC SUPPLY SHORTAGES MAY DEVELOP DURING THE 1980S, WITH THE POSSIBILITY THAT INADEQUATE MINING AND MILLING CAPACITY COULD CAUSE SHORTAGES AS SOON AS THE EARLY 1980S.

DOMESTIC SUPPLIES ARE DECLINING AND AVAILABLE ONLY AT INCREASING PRICES. THE GENERAL ACCOUNTING OFFICE RECENTLY REPORTED THAT ERDA HAS NO BETTER IDEA OF URANIUM RESERVES THAN THE FPC HAS OF NATURAL GAS RESOURCES. I DO NOT BELIEVE THIS

OBSERVATION WAS INTENDED AS A COMPLIMENT. IT IS TRUE AMERICAN UTILITIES COULD TURN TO FOREIGN SUPPLIES SINCE THE U.S. RECENTLY LIFTED ITS EMBARGO ON URANIUM IMPORTS. HOWEVER, THE AVAILABILITY AND PRICES OF FOREIGN RESOURCES ARE LESS CERTAIN THAN OUR OWN. OF IMPORTANCE TO SOME IS THE FACT THIS COURSE OF ACTION WOULD LEAD TO FURTHER DEPENDENCE ON INSECURE NONDOMESTIC SUPPLIES. THE RECENTLY REVEALED RIO TINTO ZINC CARTEL CERTAINLY BEARS OUT THE VALIDITY OF THIS CONCERN.

FIFTH, IS BREEDER REACTOR/COMMERCIAL REPROCESSING. IN LARGE PART DUE TO THE PROBLEMS DISCUSSED, PARTICULARLY THE ESCALATING COSTS OF SUPPORTING NUCLEAR FUEL CYCLES AND SUPPLY AVAILABILITY AND PRICE PROBLEMS, THE NUCLEAR COMMUNITY HAS PROPOSED CONVERSION FROM THE UNCLOSED FISSION FUEL CYCLE TO MORE COMPLEX CYCLES. THE LATTER INVOLVE THE REPROCESSING OF FISSION REACTOR FUEL TO RECOVER FISSIONABLE URANIUM AND PLUTONIUM AND THE USE OF BREEDER REACTORS TO INCREASE THE POWER PRODUCTION AVAILABLE FROM THE LIMITED URANIUM RESOURCE BASE.

INCREDIBLY, ALTHOUGH NEITHER TECHNOLOGY, I.E., REPROCESSING OR BREEDERS, HAS BEEN COMMERCIALLY DEMONSTRATED, WE ARE ASKED TO ACCEPT NEW AND UNKNOWN TYPES OF HEALTH AND SAFETY RISKS AND THE INVESTMENT OF MASSIVE QUANTITIES OF CAPITAL. THE LONG HISTORY OF FAILURE IN THE ATTEMPTS TO INSTITUTE COMMERCIAL FUEL REPROCESSING ARE WELL KNOWN. NO FACILITY CURRENTLY EXISTS TO DO SO. AS MIGHT BE EXPECTED, ATTEMPTS ARE CURRENT TO PROVIDE PUBLIC FUNDING TO COMPLETE THE MOST RECENT EFFORT AT BARNWELL, SOUTH CAROLINA. UNCERTAINTIES IN REPROCESSING ECONOMICS JUSTIFY

THE SUSPICION THAT IT MAY COST MORE TO REPROCESS THE FUEL THAN THE RECOVERED URANIUM AND PLUTONIUM IS WORTH. IT MAY BE THAT THIS CONSIDERATION EXPLAINS THE PRIVATE SECTOR'S UNWILLINGNESS TO COMPLETE THE BARNWELL FACILITY.

IF, BECAUSE OF URANIUM SCARCITY, A BREEDER TECHNOLOGY MUST BE DEVELOPED TO JUSTIFY THE CAPITAL INVESTMENT IN LIGHT WATER REACTORS, IT WOULD SEEM PRUDENT TO KNOW MORE ABOUT BREEDER TECHNOLOGY BEFORE GREATLY EXPANDING INVESTMENT IN LIGHT WATER REACTORS.

WHAT DO YOU IMAGINE THE PUBLIC REACTION WILL BE WHEN THEY LEARN THAT BY THE PHRASE "HYPOTHETICAL CORE DISASSEMBLIES" THE NUCLEAR COMMUNITY MEANS NUCLEAR EXPLOSION?

A FURTHER POINT, WHICH IS QUITE TOPICAL, IS THE FACT BREEDERS WILL INEVITABLY RESULT IN A COMMERCIAL PLUTONIUM ECONOMY.

A CURRENT GENERATION FISSION REACTOR PRODUCES PLUTONIUM AT AN ANNUAL RATE OF ROUGHLY 150 KG.

PLUTONIUM OFFERS TWO MAJOR THREATS. FIRST, IT IS HIGHLY TOXIC AND MINUTE AMOUNTS INHALED OR INGESTED ARE FATAL. SECOND, IT IS THE MATERIAL OF WHICH THEODORE TAYLOR SAID: "THERE IS GOOD, BETTER, AND WORSE, BUT THERE IS NO NON WEAPONS-GRADE PLUTONIUM INVOLVED IN THE NUCLEAR INDUSTRY". ROUGHLY 10 KG OF THE MATERIAL IS ADEQUATE FOR THE CONSTRUCTION OF A CRUDE FISSION BOMB.

THE COMMITMENT TO A REPROCESSING/BREEDER TECHNOLOGY AND A PLUTONIUM ECONOMY WILL INEVITABLY INVOLVE THE POSSIBILITY THAT PLUTONIUM WILL BE ACQUIRED BY IRRESPONSIBLES, WHETHER TERRORIST GANGS OR TERRORIST NATIONS.

ALL THE QUESTIONS POSED AND OBSERVATIONS MADE INDICATE TO ME THE NEED FOR ASSESSING ALL ASPECTS OF THE FUEL CYCLE. ASSUMING WILLINGNESS TO MAKE SUCH AN EFFORT, WHAT SHOULD BE ITS NATURE?

THERE ARE SEVERAL MECHANISMS WHICH MIGHT BE USED TO UNDERTAKE THE ASSESSMENT. I AM NOT PREPARED TODAY TO RECOMMEND ONE OVER ANOTHER. WHICHEVER MECHANISM SELECTED, IT SHOULD AT THE OUTSET BE FORMAL AND PUBLIC.

BY FORMAL IS MEANT A DECLARATION OF PURPOSE IN A MANNER SUFFICIENT TO GIVE MAXIMUM NOTICE TO ALL INTERESTED PARTIES; AND, BY PUBLIC IS MEANT THE OPPORTUNITY FOR FULL PUBLIC PARTICIPATION AND EXPOSURE TO THE PROCESS.

IN ADDITION, THE ASSESSMENT PROCEEDINGS SHOULD BE FAIR, COMPREHENSIVE, AND OPEN. THEY SHOULD BE ACKNOWLEDGED BY ALL TO BE SUCH.

THE NEED FOR FAIRNESS SEEMS OBVIOUS. WE HAVE CLEARLY ESTABLISHED OVER RECENT YEARS THAT STRONG VIEWS ARE HELD BY MANY MEMBERS OF SOCIETY ON THE SUBJECT. IF AN EFFORT AT NATIONAL ASSESSMENT IS TO HAVE ANY USEFUL RESULT, IT MUST BE CONDUCTED AS AN INVESTIGATION AND ANALYSIS, NOT AS A MEANS TO SUPPORT A PRE-DETERMINED CONCLUSION.

THE NEED FOR COMPREHENSIVENESS IS PERHAPS MORE SUBTLE, BUT, EQUALLY DEFENSIBLE. THE CONSIDERATION OF THE ISSUES LISTED ABOVE, WITHOUT CONSIDERATION OF THE SYNERGISMS BETWEEN THEM, IS SIMPLY NOT ADEQUATE. WE NEED ANALYSIS OF THE NUCLEAR FISSION COMMITMENT, NOT SIMPLY THE COMPONENT ISSUES. A TECHNOLOGICAL "SOLUTION" TO THE WASTE DISPOSAL PROBLEM WOULD NOT ELIMINATE

WASTE DISPOSAL AS A CONSIDERATION IN THE DEBATE OVER THE NUCLEAR COMMITMENT; IT WOULD SIMPLY ALTER THE EFFECT OF WASTE DISPOSAL CONSIDERATIONS ON THE ULTIMATE COMMITMENT DECISION.

THE REQUIREMENT THAT SUCH AN ASSESSMENT BE OPEN ARISES NOT SIMPLY FROM TODAY'S POLITICAL CLIMATE, BUT FROM THE FAILURE OF CLOSED DECISION PROCESSES TO ADEQUATELY DEAL WITH THE ISSUE, AND THE ISSUE IS ESSENTIALLY ONE OF NATIONAL COMMITMENT. TO THE EXTENT THAT THE ISSUE IS ONE OF RISK ASSESSMENT, THE RISK IS TO THE PUBLIC. TO THE EXTENT THAT THE ISSUE IS ONE OF ECONOMICS, THE COSTS WILL BE BORNE LARGELY BY THE PUBLIC, AND PERHAPS MOST CRITICALLY, THERE IS NO JUSTIFICATION IN AMERICAN POLITICAL PRACTICE FOR THE USE OF ANYTHING BUT AN OPEN PROCESS.

FINALLY, I WANT TO DEAL WITH THE CONSEQUENCES OF THE ACT OF ASSESSING ITSELF.

FOR PURPOSES OF ARGUMENT, I WILL CONCEDE THE POSSIBILITY THAT ASSESSMENT MIGHT PROLONG THE PRESENT PAUSE IN NUCLEAR DEVELOPMENT. BUT AN EXTENDED PAUSE WILL NOT HAVE PROFOUND EFFECTS.

IF THE ASSESSMENT DETERMINES THAT THE NUCLEAR PATH, EITHER THE PRESENT FUEL CYCLE OR SOME OTHER, IS WHAT THIS NATION SHOULD FOLLOW, THEN INTERIM ALTERNATE SOURCES WILL HAVE BEEN USED ONLY FOR A RELATIVELY SHORT PERIOD. TWO RESEARCHERS AT MIT, PAUL JOSKOW AND MARTIN BAUGHMAN, RECENTLY INCLUDED SUCH A PAUSE AS ONE SCENARIO IN A COMPUTER ANALYSIS OF THE FUTURE OF THE U.S. NUCLEAR INDUSTRY. THEY CONCLUDED THAT THE LONG-TERM EFFECT WOULD BE RELATIVELY SMALL, BOTH IN TERMS OF ELECTRICITY PRICES AND THE NUMBER OF NUCLEAR POWER PLANTS THAT WOULD EVENTUALLY BE CONSTRUCTED.

ON THE OTHER HAND, IF THE RESULT OF THE ASSESSMENT IS THAT WE SHOULD NOT BUILT MORE NUCLEAR POWER PLANTS, THEN ALTERNATIVE OPTIONS BECOME MORE URGENT. BUT AT LEAST WE WILL KNOW WHAT WE MUST DO AND CAN BEGIN PROMPTLY.

OF OVERRIDING CONCERN TO ME IS THAT THIS POLICY I HAVE OUTLINED PROVIDES FOR A SAFE-FAILURE. THAT IS, IF THE POLICY ADOPTED PROVES TO BE IN ERROR, THE CONSEQUENCES WILL BE MINIMAL. WE WILL NOT HAVE MADE A POLICY DECISION BASED ON ASSUMPTIONS WHICH ARE LATER FOUND TO BE INCORRECT COMPELLING ABANDONMENT OF THE ENTIRE PROGRAM.

WHILE TECHNICIANS AND ENGINEERS SHOULD STRIVE FOR FAIL-SAFE DEVICES, IT SEEMS TO ME THOSE RESPONSIBLE FOR THE PUBLIC INTEREST IN POLICY SHOULD ALWAYS RECOGNIZE THE POSSIBILITY OF BEING WRONG AND STRIVE FOR THE SAFE-FAIL SOLUTION.

IF IT IS LEARNED THAT NUCLEAR ISSUES CAN BE ACCOMMODATED AT A LEVEL OF RISK AND PRICE THE PEOPLE ARE WILLING TO PAY, THEN THE CONSEQUENCES OF ASSESSMENT WILL BE MINOR.

TODAY'S POLICY, ON THE OTHER HAND SEEMS TO BE A BET ON A LONG SHOT--A COMMITMENT TO A HIGH CONSUMPTION, HIGH ENERGY PRODUCTION PATH ON WHICH EVERYTHING MUST WORK IN A FAIL-SAFE MANNER. BUT IF WE FIND WE CAN'T CLOSE THE FUEL CYCLE OR CAN'T SOLVE THE PROLIFERATION PUZZLE, WE WILL BE IN THE POSITION OF THE PERSON WHO FINDS THE PATH TAKEN HAS LED HIM TO A PRECIPICE.

LET ME CONCLUDE WITH THE HOPE THAT THE ASSESSMENT, IF UNDERTAKEN, RESULTS IN THE IDENTIFICATION OR DEVELOPMENT OF MEANS WHICH WILL ENABLE POLICY PLANNERS TO RETURN TO THE EARLIER DAYS OF ENTHUSIASM WHEN NUCLEAR ENERGY WAS THOUGHT TO BE ENVIRONMENTALLY CLEAN AND ECONOMICALLY ABUNDANT.

THANK YOU.